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1951 - 1952

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.

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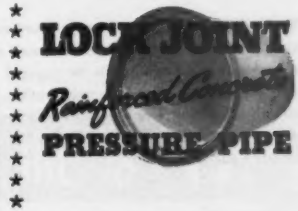

It really pays to

TAKE GOOD CARE OF YOUR METERS

SOME PRACTICAL HINTS ON METER MAINTENANCE

HAVE REGULAR REPAIR SCHEDULES

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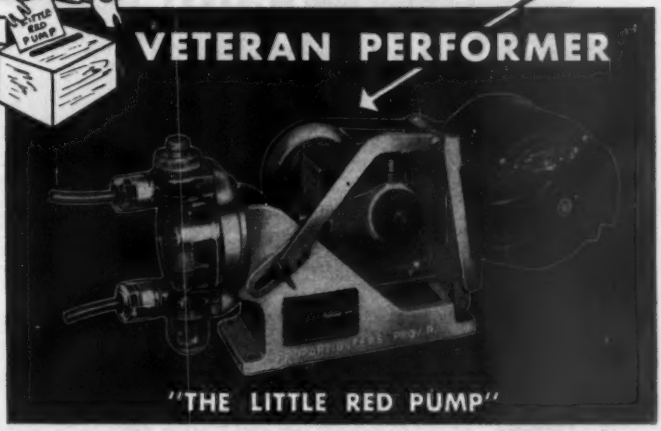

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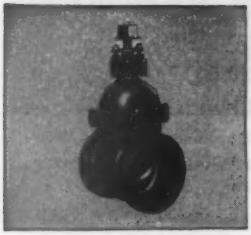

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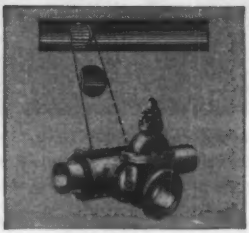
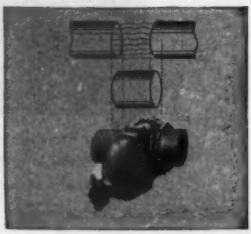


Tapping Sleeves and Valves, for making branch connections (sizes 2" thru 42") under pressure to cast iron, steel, asbestos-cement or reinforced concrete pipe of any size.



Inserting Valves, for installation under pressure in cast iron, steel or asbestos-cement pipe. Sizes 4" thru 48".

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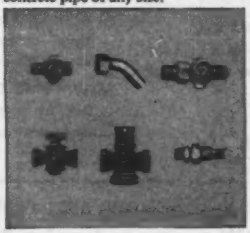
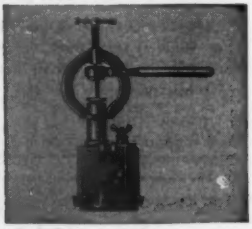


Water Service Brass Goods: corporation—curb cocks, couplings and other fittings for copper tube, lead and iron pipe services.



Corporation Tapping Machines. With the SMITH Tapping Machines corporation cocks can be instal ed under pressure. The machine is compact and easy to operate.

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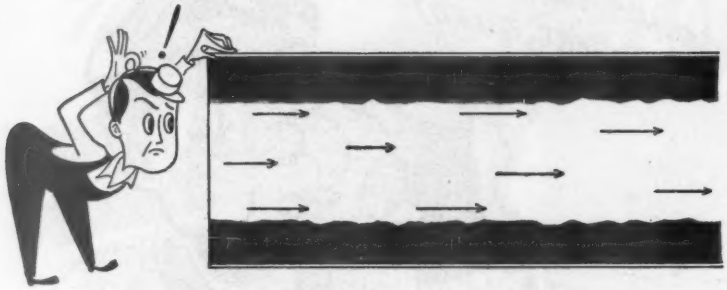
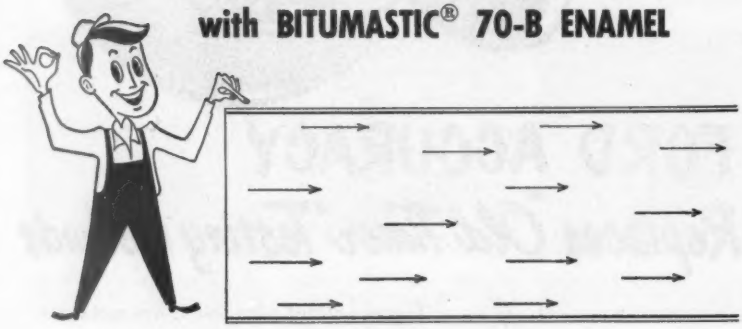


. . . when you protect pipe lines with BITUMASTIC® 70-B ENAMEL



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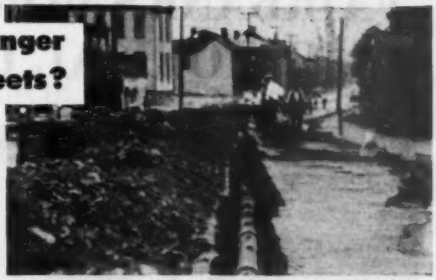
TRANSITE PIPE last longer West Virginia city streets?



Transite Pipe was first installed in this West Virginia city in 1935. In addition to heavy street traffic, it has withstood soil conditions so destructive that the pipe previously used had a service life of only two to three years. When the Transite main was recently uncovered to insert a tap into the line, the pipe was found in as good condition as the day it was laid!

it's reinforced with ASBESTOS for lasting strength

THERE IS GOOD REASON why Transite* Pressure Pipe—shown in the city street above—has already far exceeded engineers' expectations for the service life of pipe used here:

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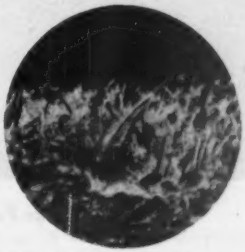

This photomicrograph shows how the tough, strong asbestos fibers are distributed uniformly throughout the structure of the pipe.

To find out more about how this modern asbestos-cement pipe can help solve your waterline problems and save you money, write Johns-Manville, Box 60, New York 16, N. Y.

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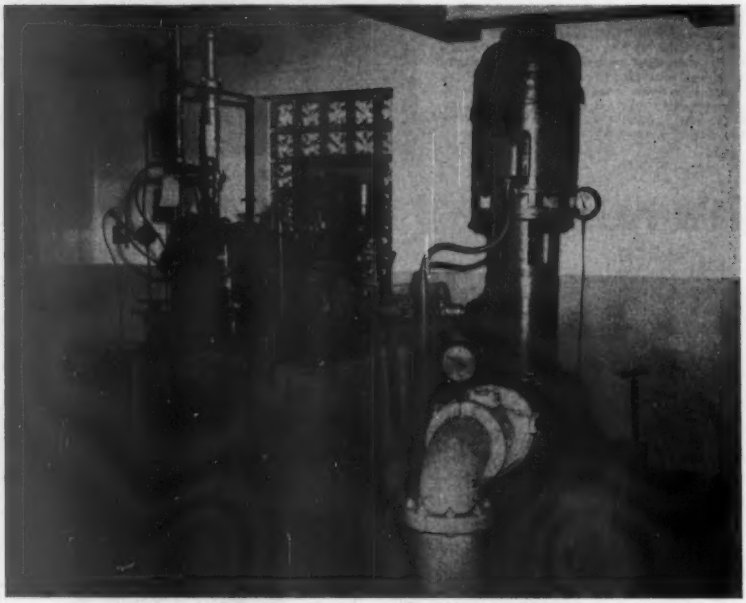

3 Stage Fairbanks, Morse-Pomona

The Fairbanks, Morse Fig. 6977, water lubricated, deep well turbine pump, pictured above has been supplying water to the town of Concord faithfully since its installation in 1949.

Set in a 24" gravel packed well, 75 feet deep and using a combination drive—electric motor, gasoline engine and right angle gear, the pump normally operates at 700 GPM at 150'TDH but can, and has, supplied Concord's entire demand of 900,000 GPD.

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New England Water Works Association
ORGANIZED 1882

VOL. LXVI JUNE, 1952 NO. 2

This Association, as a body, is not responsible for the statements or opinions of any of its members

HIGHLIGHTS OF THE DEFENSE PROGRAM AND CONTROLLED MATERIALS PLAN AS AFFECTING WATER WORKS

BY WALTER L. PICTON*

[*Read September 12, 1951.*]

Water supply, in adequate quantity and proper purity, is an essential service for community life, health, our modern standard of living, and all types of industrial operation. As a part of our economy this service has grown from the early picture of the village well to one of the major essential industries of our nation.

Effect of World War II

During World War II, the pressure of the requirements for support of war activities absorbed so much of our material and manpower that we were forced to defer much of our needed water-works expansion and even deferred so much of our needed maintenance and replacements that some systems were operating without safe reserves for emergencies. As a result of so much deferral, there was built up a heavy backlog of new construction required to give adequate service to our increased population and allow full use of newly developed modern conveniences, which have greatly increased our per-capita water use.

Post-War Planning and Progress

During the last stages of World War II and in the period immediately following the war, the leaders of our water-works systems reoriented their planning, in order to provide adequate service for present and future needs. The initiation of these programs was temporarily handicapped, first by extreme shortages of material and equipment and, secondly, by rapid rise in material and labor cost,

*Water and Sewage Works Adviser, Office of Program and Requirements, Defense Production Administration, Washington, D. C.

which quickly antiquated even the estimate prepared with careful forethought.

Thus, our real post-war stride in the field of water-works construction was just reached in 1950, following the readjustment of prices (or slight recession) which occurred in 1949.

Korean Emergency

Our hopes of progress and of reduction in the backlog of needed construction were dimmed when the aggression occurred in Korea. It was immediately necessary for our nation to enter a stage of partial mobilization, in order to stop the aggression and at the same time rebuild for defense.

The emergency required that we speed up the stockpiling of critical materials and increase the production of the material and equipment required for defense. At the same time, realizing that this drain upon our production might continue for some time, we initiated the defense industrial expansion program, to increase our capacity for production of the products that would be in greatest demand for our combined defense and civilian requirements.

Since, at the beginning, some materials were in short supply to meet both defense and civilian requirements, it was necessary to provide for set-aside of certain percentages for priority use for defense purposes.

Defense Program

The objectives of our defense program are to increase the production of the key materials to quantities that will be sufficient to support our efforts to stop aggression, build up our defense, and arm our Allies, and at the same time provide the requirements of our civilian life. Until these objectives are attained, it is necessary that some activities be restricted for the benefit of defense and defense support. It is hoped, however, that if the program can continue its present progress, we may attain these objectives by some time in the latter part of 1953.

Defense Administration

In setting up the machinery for defense administration the Office of Defense Mobilization was soon established, to guide our entire defense mobilization. Later the Defense Production Administration was established for the specific purpose of guiding our production activities.

Within this general framework existing federal agencies were delegated the operating responsibilities as claimant agencies to perform the ground-work functions of mobilizing particular industries. One of the largest of these is the National Production Authority within the Department of Commerce, which has the responsibility of the mobilization of most of our industries and also is the home of a few of the non-industrial claimant fields.

Water Resources Division in NPA

In May, 1951, a beginning was made to provide a focal point for water works. In July the official announcement was made, establishing the Water Resources Division in the National Production Authority as the focal point for water supply and disposal. This division was delegated the responsibility as claimant agency to cover water and sewage works, municipal and industrial, and water wells for farm, domestic and irrigation use.

The Controlled Materials Plan or CMP

I shall try to give you a simple explanation of the controlled materials plan. In essence, it is a plan for the control of our entire economy's use of all material, energy and manpower through the control of the use in the distribution of certain key materials—for instance, the mill-type products of steel, copper and aluminum. In order to put this into operation, it is necessary to develop a summation of the available supply of these materials and the quantities required by each of our fields of operation. After a set-aside or allotment of the essential quantities to meet defense (including military, AEC, Foreign Military Aid, etc.), allotments can then be made to support the essential operations of the key defense-supporting activities, such as steel and aluminum production expansion, transportation, electric power, and petroleum products.

All of the other essential areas of our activities are considered in proper order and balance and are supported in their essential activities to the extent possible. Of course, in this distribution there is planned the reduced production of general civilian-type products within reasonable limits, an attempt being made to avoid any severe shortages or unemployment.

Operational Methods

In actual operation the claimant agency plays an important part as the center for the special knowledge in its particular field. Each claimant agency maintains constant contact and keeps fully informed on the construction, operation, and service requirements in its field and the portion of such activities which may be vital on account of connection with public health or defense activities. With this information at hand, the claimant agency formulates a program for a year ahead, covering maintenance, operation and new construction, and submits this to the Defense Production Administration with estimates of the material requirements for carrying on the proposed program.

The Defense Production Administration staff studies and analyzes the proposed program and the requested material and submits the results to the Requirements Committee with their recommendations after each effort to place the programs in proper balance, with special consideration for the most essential portions.

The Requirements Committee, with all advice obtainable, considers all of these programs in proper balance with the knowledge of the availability of supply of critical materials, makes its determination of the allotments of materials to each claimant and suggests suitable program revisions. Such allotments are made sufficiently in advance to allow the claimant agency to consider individual requests for material and issue material authorizations in time for the orders to be placed on the mill schedules.

Some reserves are held back by the Requirements Committee and by the claimant agency to meet unexpected contingencies and emergencies, and provisions are made for appeals in case of special hardships.

This entire procedure is repeated each three months as quarterly allotments are made to the claimant fields.

Effect Upon Present Water-Works Program

The effect of our present emergency is to require a reduction in the increasing trend of new construction for water works which, as I have said, was just reaching its post-war stride. It must now be held down to the minimum essential for public-health and defense-supporting needs. In this I do not mean that we are expected to sacrifice our modern standard of public health or of living.

The most essential portion of this new water-works construction will still continue in large volume, since expanded industry, population shifts and public health standards will require the provision of new facilities in many places. At the same time there will be some competition for the limited supply of special equipment, since industrial and military water-works expansion will also require the same types of equipment.

Some relief can be obtained in the total requirements by deferral of construction that is designed solely for future needs and by rephasing the requirements where it is possible to do so and complete the project at the time needed.

The Prospects Ahead

We can anticipate that the next two or three quarters will probably be increasingly tight with respect to controlled materials and that will continue until the end of 1952 or early in 1953. After that there should be a gradual easing of this condition, and by late in 1953 it is hoped that a better balance may be attained. By that time we should have increased our production capacity sufficiently to be able to care for the combined defense and civilian needs.

Your Operations During Period

During this period you can individually assist by coöperating fully with your claimant agency and the other collaborating federal and local agencies, such as the State Health Departments, U. S. Public Health Service, and Water Works Association, in furnishing any information that they may desire to assist them in formulating their program and judging your individual requests.

The whole picture will become clearer through your efforts to plan in advance, by carefully estimating and scheduling your requirements. This information, submitted with explanation of the essentiality of your particular project, will assist the Water Resources Division in judging the case.

Since you understand the conditions, you can judge the immediate or future necessity for the project and defer, or postpone temporarily, all but presently essential construction.

Outcome

You should understand that full consideration of the problems in your field will be given by the top-level defense authorities and every effort will be made to support the necessary construction and maintenance for water supplies. I am convinced that our waterworks engineering ingenuity and energy can weather such difficulties as these and still render service according to our historical record for serving the American people in their homes and in industry. Just as soon as world conditions and our defense program will permit, controls will be released, so we can look forward to a period when we hope we can resume normal living and progress.

CIVIL DEFENSE OF NEW ENGLAND— RECENT DEVELOPMENTS

BY ALBERT D. O'CONNOR*

[*Read September 12, 1951.*]

In considering the civil defense program in New England, as well as throughout the Nation, it is well to remember that general agreement exists on these three facts: (1) The United States is menaced by Russia. (2) A national system of defense against this menace is necessary. (3) National defense consists of a strong Army, Navy, Air Force, Marine Corps, *and* protection on the home front.

The essential elements of national defense are the willingness and the ability of an entire nation to protect itself on *all* fronts. National defense depends upon people, upon their will to defend what they have, their resources, and their production. Unless the people, their will to fight, and their resources are protected, any national defense system is a house of cards that will collapse, just as Germany and Japan collapsed in World War II.

History has proven that military strength alone cannot protect a home front. Recognizing this fact, Congress, after long and careful study, passed the U. S. Civil Defense Act in 1951. This act established the Federal Civil Defense Administration and charged it with developing a civil defense plan for the Nation. This act also promised Federal financial help to the states and cities in building their local defense against enemy attack.

The act which Congress passed also provided for the appointment, by the President, of a National Civil Defense Advisory Council. This Council is a bipartisan group, composed of public-spirited citizens, including the governors of three states and the mayors of three cities, with independent views on civil defense.

This Council held an organization meeting on June 15, 1951, and issued the following statement:

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". . . The need for civil defense does not depend on isolated world incidents or on the daily headlines. The need for civil defense will continue so long as there are forces of aggression in the world. Civil defense against modern weapons is not something which can be created at a moment's notice to fit a sudden need. Civil defense must be ready at all times to meet any need which might arise. Once the bombs hit, it will be too late. . . .

"No part of America is immune. The people of the smaller cities and towns who need not fear direct attack must nevertheless be fully equipped and trained to go to the aid of the major cities which would be attacked. . . ."

Now what has the Federal Civil Defense Administration done to date? In developing a civil defense plan for the Nation, this Federal agency—within the monetary limitations set by Congress—has engaged in such activities as the following:

First of all, it has given advice and assistance to the states in effecting interstate compacts. These compacts provide for mutual interchange of assistance in an emergency. All of the states in this region have such compacts, and they are now working on supplemental agreements to make these mutual arrangements truly effective. The Northeast Regional Office of the Federal agency has been active in promoting developments for adequate mutual aid.

The Federal Civil Defense Administration has also initiated a program of matching funds. Through this program, Federal moneys are made available to match state and local expenditures. The Congressional appropriation of last fiscal year provided $20,000,000 in matching funds for medical organizational equipment and supplies. This money was allocated to the states which have the most critical target areas. On the basis of requests from the states, the Federal Civil Defense Administration is now arranging for the procurement of the supplies and equipment desired under this program. The Federal matching funds provided to date are considered quite inadequate by prominent state and local officials. As you know, Congress is now considering civil defense appropriations for the present fiscal year. These new appropriations, as requested by the Federal Civil Defense Administration, provide for additional matching funds.

One of the most important things the FCDA has done has been to provide for public information, and for education and training. Many publications and films have been distributed to the states, and these have proved useful in developing state civil defense programs. Particularly see the pamphlet on Water Supplies for War-Time Fire Fighting (TM-9-1), which is available at the U. S. Government Printing Office at 5¢ per copy. More help of this type will follow. With respect to education and training, one of the first things FCDA did was to arrange for the training of technicians in radiological monitoring at Brookhaven, the AEC installation on Long Island. These experts have since gone back to their respective states and have there

initiated training of state and local radiological monitoring teams. For example, both Maine and Connecticut have conducted training schools for radiological monitors. The Northeast Regional Office has helped to obtain instructors and equipment for these training courses. The Staff College at Olney, Md., and our three Technical Training Centers—one in California, one in Oklahoma and one at Olney, Md.—are engaged in a program to train individuals for civil defense operations and, in particular, for their specific functions in such civil defense activities as fire fighting, rescue work, public facilities, mutual aid, mobile support, engineering, transportation, and so on. As a further example of our training activities, civil defense workers in four widely-separated Eastern cities will participate this Saturday in the first test of theater television as a training technique. A live program, originating in Washington, will be seen on the screens of theaters in New York, Baltimore and Philadelphia, as well as in Washington, by more than 11,000 spectators. If the experiment is successful, a series of TV training programs may soon be inaugurated, to give simultaneous and standardized instructions to civil defense workers throughout the country.

So much for what the Federal Civil Defense Administration has done and is doing today. With your permission, I should now like to say something about what is happening here in New England.

I have spent a good part of my time, during the last half-year, in traveling from one state to another in this region and talking with people about civil defense. Most of my contacts have been with civil defense officials, but I have also talked with many other people. Thus I have had an opportunity to see the picture as a whole. I find that there are still quite a few people in New England who simply cannot get used to the fact that today, for the first time since the Indian wars, we are in danger of being attacked in our own homes. It is a hard fact to learn, but nevertheless we are gradually learning it. During the last half-year this fact has been presented to the public in many ways, over and over again—in talks by public officials, in films and over the radio, in TV programs, in pamphlets and magazine articles, and in newspaper editorials. This repetition has had its effect, as I can testify from my own observation. There are still people here who doubt our danger, but their number is smaller today than it was last spring. The great majority of New Englanders today, as I see them, are sold on civil defense and ready to do their part.

Progress has been made in civil defense since last spring. That is true for the country as a whole, and it is true for the Northeastern

part of the country in particular. Some states are farther ahead than others, of course, and the same can be said about communities. But in most places we have now passed beyond the planning and paper stage. We are training volunteers in the actual tasks they will have to perform in time of disaster. We are holding civil defense exercises to test out our plans, our facilities and our personnel. In these tests we are simulating, in so far as we can, actual disaster conditions. Some of these tests are complete civil defense operations, in which all of the emergency services, that will have to function like clockwork when the bombs fall, are being tested in advance. New York State has already held three big operations of this type—at Utica, Niagara and Rochester—and it will hold a fourth this Saturday—at Syracuse. Here in Massachusetts, the first big test of a metropolitan area's defense forces is scheduled for late this fall. Rhode Island is preparing for the first statewide operation in October.

I should like to emphasize one thing about these big civil defense operations. Our purpose in conducting them is *not* to prove that our civil defense set-up is good. We are running these tests for the specific purpose of finding out what's wrong, so that we can correct it. Every civil defense test to date has revealed weak spots and I expect that every new one will do the same, if such weaknesses exist.

What I have told you today will indicate pretty clearly to you, I think, that, in my opinion and from my fairly wide observation, our civil defense program in New England is coming along well. It is handicapped by inadequate funds, but it is shaping up in spite of all difficulties. We are much closer to being ready for the enemy today than we were six months ago. But, in my opinion, we are still far from being completely prepared. We have moved forward, but we have got to move faster.

Now I hardly need to tell you people how essential your work is to the community in time of peace. But I should like to emphasize just as strongly as I can that your work will be even more essential, should atomic bombs start falling. Blast, fire, and radiation are the three great destroyers released by an atomic explosion, but fire is the most destructive of the three. And the number-one problem

in fighting fire is water—where to get it, how to get it, and how to keep it flowing.

This problem is a greater problem in war-time than in peace-time. For peace-time water supplies are totally inadequate for fighting war-time fires. That was one of the lessons we learned in World War II. We have got to plan accordingly. When an attack comes, survival or disaster for millions may rest on two things—first, keeping in service as much of the public water-supply system as possible, and secondly, providing auxiliary water supplies, separate from the public water system, for fire fighting.

The great fires in Germany and Japan during the last war proved conclusively that when a big city is attacked, its public water supply can be exhausted or made completely ineffective in a very short time. In Tokyo, for example, all efforts to combat the flames were futile 30 minutes after the first bomb dropped. Water mains were broken in 847 places by high-explosive bombs and the city's water system was completely disrupted. This happened in spite of good planning before the attack.

Let me emphasize again. Auxiliary sources of water supply *must* be utilized. These sources, of course, include the ocean, lakes, rivers, ponds, streams and wells, and even private water-supply systems in public and private institutions and at industrial and commercial plants.

Let me emphasize one more fact. In your field of work, as in all fields of work essential to our civil defense program, you will need volunteer help, trained to act in an emergency and equipped with the necessary tools. When the bombs fall, you will need all the trained help you can get.

Most of you people are already actively coöperating with your local civil defense director, I am sure. In this respect you are following the lead of state water- and sewage-works officials in all parts of the country. In 39 states, I understand that the Chief Sanitary Engineer is part of the State Civil Defense Organization. Twenty-nine of these engineers are in charge of environmental sanitation in civil defense, seven are state water coördinators, and three serve on the State Civil Defense Advisory Board. In 20 states, a water-works executive is part of the State Civil Defense Organization.

You people have your work cut out for you. Safeguards must be installed which will protect existing facilities, and additional sources of supply must be located and made ready for use. Protective measures should include fences, control over admittance to plants, guard systems on a 24-hour basis, a warning signal system, protection of water mains and valves, and screening of all personnel. Adequate precaution should be taken at all times to prevent and counteract contamination. Equipment should be decentralized as much as practicable. Supplies should be stockpiled and stored in a place safe from air attack or sabotage. A radio communication system should be provided. Personnel should be interchanged, so that the system will not be handicapped by the loss of key people.

That is quite a list of things to do. Much credit is due to those of you, here today, who have already made considerable progress in accomplishing these things.

We have our work cut out for us at the regional level, too. I am not going to give you a detailed list of our own tasks and duties. But I might just indicate quickly, in a general way, one important phase of our work—that part which involves interstate compacts and supplemental agreements. Since the Northeast Regional Office of FCDA is primarily concerned with interstate activities, it is our job to follow through on the following objectives:

A. A sound and consistent method for evaluating needs in a disaster area.

B. A method for adjudging the most efficient destination of the resources available to a disaster area.

C. Arrangements for consistent and effective command and control, relative to the resources despatched from one state to another, through the echelons of the sending states, as well as of the receiving states, and with some type of transitional control between the states.

D. A method for adjudging the facilities which could most effectively be used in evacuation and movement from specific disaster areas, and coördination of evacuation plans, both on a regional and inter-regional basis.

These are some of the duties and responsibilities of the regional office.

All of us face a challenge today. This challenge faces us not only in the fields of diplomacy and armed forces. It also faces us in the field of civil defense—in the protection of our homes and communities and our production potential. All of us are concerned. All of us must do our part to build up a strong civil defense program and to keep it strong, so that it will be there when we need it. That is the challenge which faces us.

Never forget these facts: (1) The United States is menaced by Russia. (2) A national system of defense against this menace is necessary. (3) National defense consists of a strong Army, Navy Air Force, Marine Corps, *and* protection on the home front.

Protection on the home front is your job.

RECENT DEVELOPMENTS—THE CAMBRIDGE WATER SUPPLY

BY HOWARD M. TURNER*

[*Read September 12, 1951.*]

Existing Water Supply

The water supply of the city of Cambridge, Mass., was taken originally from Fresh Pond in Cambridge in 1856. This supply was supplemented in 1887 with water brought in a conduit from a storage reservoir constructed on Stony Brook, a tributary of the Charles River, in Waltham and Weston. In 1897 a larger storage reservoir was completed on Hobbs Brook, a tributary of Stony Brook, in Waltham, Lincoln and Lexington. The water from the Hobbs Brook Reservoir flows in an open channel from Hobbs Brook to Stony Brook Reservoir and thence is drawn through a conduit to Fresh Pond, whence it is pumped for the supply of the city (see Fig. 1). The Payson Park distribution reservoir of 43 mil gal (mg) capacity is located in Belmont.

Stony Brook Reservoir contains 402 mg of water. The dam is of earth with a stone masonry spillway and gate structure and is founded in part on sandy and gravelly material. There is reason for believing that considerable leakage occurs. The net drainage area is 16.50 sq mi, so that the storage volume is only 24 mg per square mile of the net drainage area. The reservoir on Hobbs Brook is much larger than the Stony Brook Reservoir, containing when full approximately 3,000 mg with a drainage area of only 7.25 sq mi, so that the storage is 415 mg per square mile. Thus, while the Stony Brook Reservoir is too small for its drainage area and overflows every year, the Hobbs Brook Reservoir is too large for it, and sometimes does not fill.

From Stony Brook Reservoir the water is carried to Cambridge by gravity, the first 4,300 ft in two 36-inch pipes, the next 8,700 ft

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FIG. 1.—PRESENT CAMBRIDGE WATER SUPPLY.

in one 30-inch and 36-inch pipe to River Street, Waltham, and thence to Cambridge in a 63-inch diameter conduit, 26,700 ft long, to the Fresh Pond weir chamber, from which a short length of 42-inch C. I. pipe leads to the filtration plant and an overflow weir discharges into the pond. One of the 36-inch pipes was laid in 1931; the rest of the conduits when the Stony Brook Reservoir was built in 1887.

Fresh Pond is a natural lake in the western end of the city with an area of 166 acres. It contains when full to elevation 17.35 a total of 1,500 mg; over 1,000 mg of this can be used by means of pumps which can draw the water down to elevation —4 (about 22 ft). Water

taken from Fresh Pond comes from the natural runoff of the Fresh Pond watershed, 1.25 sq mi, from ground-water storage and inflow and from some of the runoff of Stony Brook in excess of the capacity of the reservoir.

The filtration plant on the shores of Fresh Pond, built in 1922, is a mechanical filter which, prior to the present improvements, consisted of a receiving chamber into which water is introduced either directly from Stony Brook or by means of the pumps from Fresh Pond. From the receiving chamber the water flows into a coagulation basin, divided into two major parts with a total capacity of 1.5 mg. After sedimentation, water is brought directly to the pipe gallery of the filtration plant. This plant consists of 16 units of 480 sq ft each, 10 of which were constructed in 1922 and six of which were added in 1932. From the filters the water flows through an aerator to a covered concrete pure-water reservoir, located under the filter beds, holding approximately 4 mg.

The present pumping station is located near the purification works and is supplied from the pure-water reservoir. It contains a Worthington cross-compound steam pump, installed in 1928, with a capacity of 20 mgd and one older pump also with a capacity of 20 mgd. The water is pumped directly into the mains leading to the city, which are connected also to the distribution reservoir in Payson Park.

In 1930-32 several important additions were made, after a complete study by Hazen and Everett, consulting engineers, as follows‡: (1) The system was completely metered. (2) The 36-in. pipe on the upper part of the conduit leading from Stony Brook was built, reinforcing the existing pipe. (3) A pumping station was built on the shore of Fresh Pond, so that the water in the pond could be lowered thereby and storage thus be provided for some of the water which was wasted every year over the Stony Brook spillway. (4) The distribution system was reinforced by the construction of a main 30-in. pipe to the east end of the city. (5) The wash water from the filter beds, which previously had been wasted to the sewer, was returned to Fresh Pond, adding about 1.5 mgd to the usable water. (6) An

‡This JOURNAL, Vol. XLVIII, No. 1.

additional sedimentation basin with a capacity of 3 mg was recommended by the engineers but was not ever built.

The results of these improvements were satisfactory. Some of the wastage over Stony Brook was utilized to give Cambridge sufficient water by storing in Fresh Pond. This wastage formerly averaged about 2,700 mg; in the last ten years it has averaged about 1,100 mg. At that time the engineers estimated the total dependable yield throughout a very dry year at 14.9 mgd, an increase from 13 mgd before the work was started. Figure 2 shows the pumpage and per-capita consumption since 1890. The decrease in the pumpage and per-capita consumption due to metering is clearly visible. The chart also shows various predictions of population and consumption which have been made from time to time.

In 1941 the total pumpage had reached 14.0 mgd and the Water Board started to investigate various ways of obtaining additional water. Wells to the west of Fresh Pond were considered, from which it was proposed to pump into the pond. Irving B. Crosby, consulting geologist, made a report on these wells, in which the availability of large amounts of ground water in this area was confirmed. This report also pointed out that a large amount of this ground water could be obtained, flowing from the ground directly into the pond, by lowering its level to say elevation —3 (about 21 ft). This was cited as an emergency supply which could always be resorted to in case of necessity. Early in 1942 a committee consisting of Professors Thomas R. Camp and Gordon M. Fair, and Frank P. Scully, later a member of the Water Board, reported that with this water thus available "no further consideration need be given to wells in this area because most of the water that could be collected by wells is already naturally available to Fresh Pond."

Various estimates were then made of the ground water flowing into Fresh Pond with the pond lowered, varying from 2 to 6 mgd. The results of an investigation made of this by the engineers of the U. S. Geological Survey in Boston were given in a paper by Henry H. Halberg and Claude M. Roberts, entitled "Recovery of Ground Water by Pumping from Water Table Ponds."* I quote the following:

*Transactions of the American Geophysical Union, Vol. 30, No. 2, April, 1949.

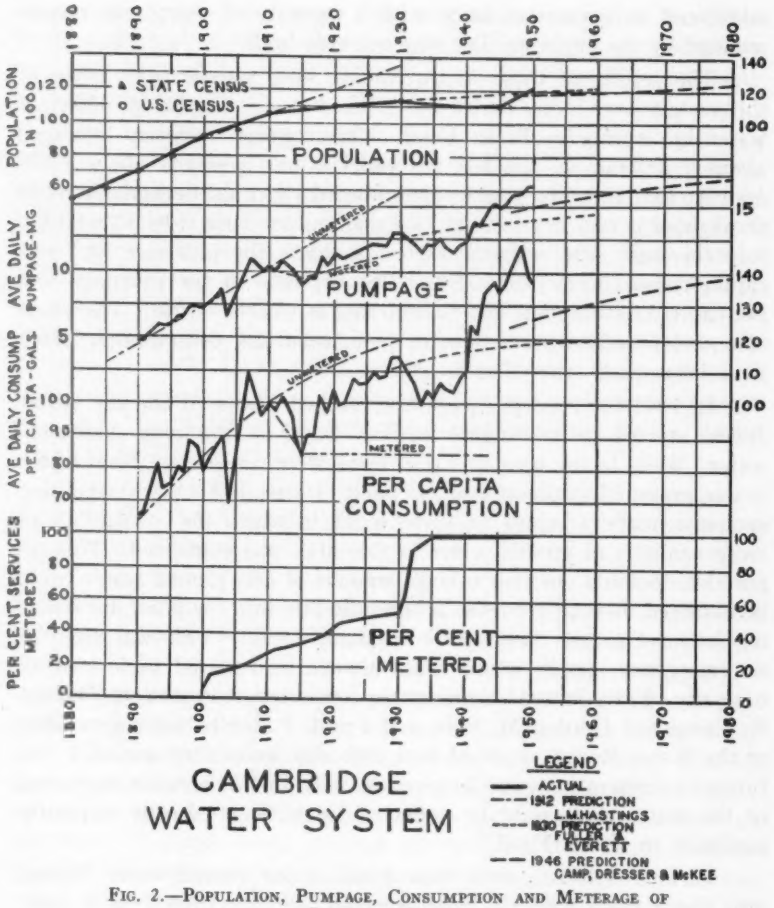


FIG. 2.—POPULATION, PUMPAGE, CONSUMPTION AND METERAGE OF CAMBRIDGE SUPPLY.

"Much of Fresh Pond is surrounded by relatively impermeable materials, but highly permeable glacial outwash lies around the western end of the pond and the area to the northwest. These water-bearing materials are underlain by ground moraine and beds of clay which extend under Fresh Pond to form an impermeable bottom. . . .

"Thus, much of the ground water that seeps into Fresh Pond reaches it after flowing through the interconnected beds of sand and gravel from the catchment areas west and northwest of the pond. However, other smaller sandy catchment areas to the north and the southwest also contribute some recharge. . . .

"Some of the changes in ground-water storage in the glacial deposits surrounding Fresh Pond have been computed by combining algebraically the figures for inflow to and outflow from the pond, and changes in pondage due to precipitation and evaporation. . . ." During the year 1944 the pond was drawn down to elevation —1.5 and the survey reports the following:

"Computations indicate that during the month of July, 1944, when the pond was being drawn down, ground water was drawn into the pond from the surrounding sands and gravels in the amount of 286 mg during the month, or about 9.2 mgd. In August, when the water level in the pond was still lower, about 246 mg were drawn from ground-water storage, representing an average rate of about 7.9 mgd. During the period when the pond was lowest, September 1-9, 1944, and when the hydraulic gradient of the water table was lowest, only about 3.1 mgd were drawn from the formations surrounding the pond."* These figures show that not only is it possible to secure a large amount of water from the underground storage around the pond, but that when that is drawn down, the ground yields about 3 mgd, which is in addition to the surface-water sources of the Cambridge supply.

Of course, this water is harder than the other Cambridge supply. When a well near Fresh Pond was test-pumped in 1931, the water had a hardness of 160 ppm when pumping began, which reached a maximum of 260 ppm after 112 hours of pumping. "Samples of water at three different depths in Fresh Pond were collected at a time when the water level was low and no water had entered the pond from Stony Brook reservoir for more than two months. Hence, at this time the water in the pond was supplied from the surrounding ground water and from precipitation. The hardness of the pond water ranged from 65 ppm at the surface to 68 ppm at the bottom."* Since the hardness of the water is regulated in any event by treatment with lime, this presents no difficulties.

This source of additional supply now finally determined was known about a long time ago. The Sixth Annual Report of the Cambridge Water Board, 1870, contained the following: "The experience of the past summer shows conclusively that the above estimate from

*Transactions of the American Geophysical Union, Vol. 30, No. 2, April, 1949.

the watershed and rainfall at Fresh Pond, Spy and Little Ponds, gives an imperfect idea of the real capacity of the Ponds, clearly demonstrating that they are fed from a fountain independent of the rainfall and watershed for any given time, defying all our powers of computation." Other reports refer to the same condition.

Connections with the Metropolitan Supply

In 1904, when the Metropolitan District Commission laid a 48-inch main under the Cambridge Common, a connection was made with the Cambridge system. This was very occasionally used in emergencies. No charge was made for the connection, the only charge being for the water that was used. In 1941 a rental charge was established for such connections. In 1943 the legislature of Massachusetts passed a law requiring cities and towns in the Metropolitan area which were found not to have a sufficient safe supply to connect with the Metropolitan system. The law provided that the Board of Health "shall report to the Metropolitan District Commission each of said towns which it finds cannot be so supplied continuously with a quantity ten per cent in excess of its average consumption during the three previous calendar years, and shall notify each of said towns of its findings with respect thereto."

In 1942 the Department of Public Health certified that Cambridge had a safe yield of only 8% in addition to the daily water consumption for the years 1939, 1940 and 1941. The city protested this decision and in accordance with the law the case was heard by a special commission appointed by the Supreme Court, at which expert testimony was introduced giving the safe yield of the supply as 17 mgd, included in which was a figure of 3 mgd from the underground water which would flow into Fresh Pond when the pond was lowered. The commission upheld the city of Cambridge. The connection with the Metropolitan which the city had for many years was cut, although an arrangement was made by which the connection could be replaced at short notice.

In 1945 the present legislation on the Metropolitan District water supply was passed to the great satisfaction, I believe, of all those cities and towns which would like to avail themselves of a con-

nection with the Metropolitan, but were prevented by the previous excessive entrance and water charges and the existence of their own supplies. Besides a refinancing plan which reduced the cost of water to $40 per mg to users within the Metropolitan area, this legislation provided (a) that a city or town which abandoned its own water supply and took all its water from the Metropolitan could enter the Metropolitan without any entrance fee; (b) that any city or town that had its own supply but desired a connection with the Metropolitan could make such a connection for a comparatively small entrance fee and purchase what water is needed on the above basis of $40 per mg. This was forward-looking legislation of great general public benefit. It enabled the city of Cambridge to consider a connection with the Metropolitan system which it had never been able to do in the past on account of the high cost.

In 1946 the Water Board began again to study the future of the Cambridge water supply. In view of the new legislation, the matter of joining the Metropolitan and giving up its own supply or connecting with the Metropolitan for emergency use was considered. The Board made a very careful study of this question. It was decided to recommend that Cambridge keep its own supply but connect with the Metropolitan for emergency and additional future supply under the provisions of the act. When the decision was finally made by the city, negotiations were opened by the city with the Metropolitan Commission and it was agreed that three connections would be made, for which the Commission fixed an entrance fee of $150,000, payable in ten yearly installments.

New Program

Starting in 1946 the Board had studies made by Camp, Dresser & McKee, consulting engineers, of four main phases of the water-supply plant:

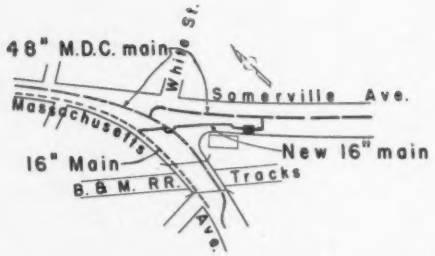
(1) Plans for connection with the MDC;
(2) The improvement of the distribution system, including the feeder mains from Payson Park Reservoir;
(3) The improvement of the filtration plant by the construction of a flocculating chamber and additional sedimentation-basin area and capacity, and

(4) A new high-lift pumping station to take the place of the present steam pumping plant.

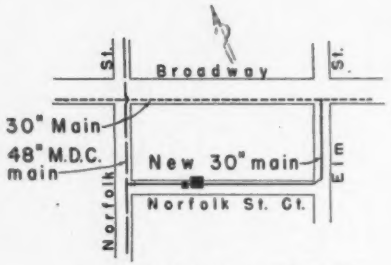
These engineers have also made the construction plans and are supervising the construction of these works. The Board also studied the question of a new maintenance and service building located at Fresh Pond. As shown on Figure 3, this program proposes to locate all the items of the water-supply plant, now scattered, in one place on the shore of Fresh Pond. This program was presented to the City Council in February, 1949, and work was started early in the spring of 1950. Following are descriptions of the various parts of this work:

Metropolitan Connections

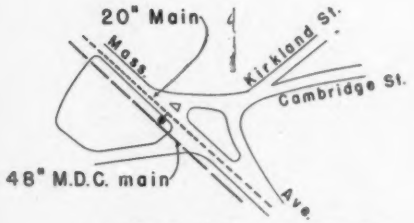
The connections with the MDC system as shown in Figure 4 were made at three points, each with a different capacity. The one at Norfolk and Broadway at the east end of the city, where consumption is large and pressure is lowest, has a capacity of 27 mgd. This connects the 30-inch main in Broadway with a 48-inch MDC main crossing the city in Norfolk Street. The one at the Cambridge Common, which replaces the former connection made in 1904, has a capacity of 12 mgd. It connects the 20-inch main in Massachusetts Avenue with another 48-inch MDC main. The one near Porter Square at the north side of the city has a capacity of 4 mgd. It connects a 16-inch city main with a new 48-inch cross-connecting main of the MDC in Somerville Avenue. These capacities are based on the proportion of the total supply that would be fed from each connection. Each connection is equipped with the necessary gate valves and Venturi meter and with automatic pressure-control valves, which can be set to open the connection when the pressure on the outflow side gets below a given amount and to reclose the gate when the flow reduces to a predetermined amount. Owing to its larger size, the connection in Norfolk Street has two 24-inch reducing valves instead of one larger one, as shown on Figure 5. The valves and meters are housed in underground chambers, on top of which there are small brick superstructures holding the instruments and providing access and ventilation. At Norfolk Street the general layout was planned and sufficient land obtained so that if in the future such a large



PORTER SQUARE

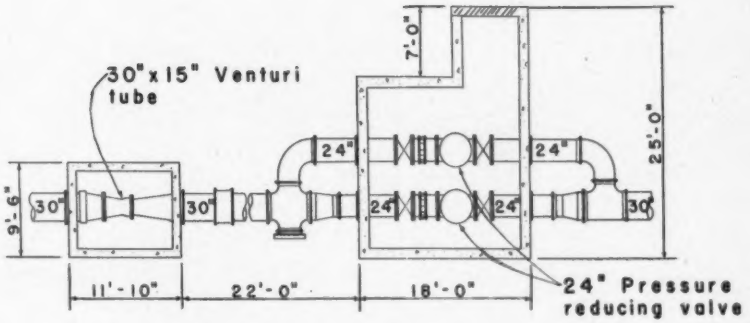


NORFOLK STREET

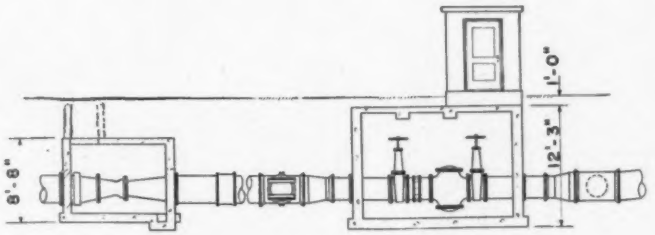


CAMBRIDGE COMMON

LOCATION PLANS

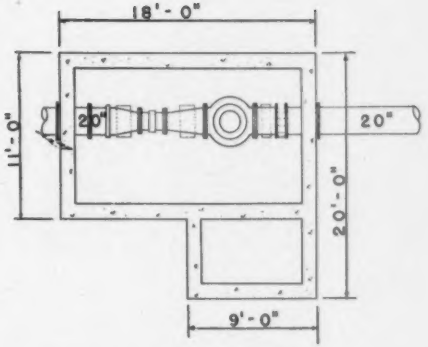


BASEMENT PLAN

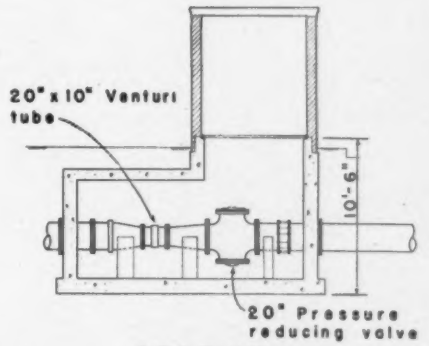


SECTION

NORFOLK ST. CONNECTION



BASEMENT PLAN



SECTION

CAMBRIDGE COMMON CONNECTION

CONNECTIONS WITH METROPOLITAN SYSTEM

FIG. 4.

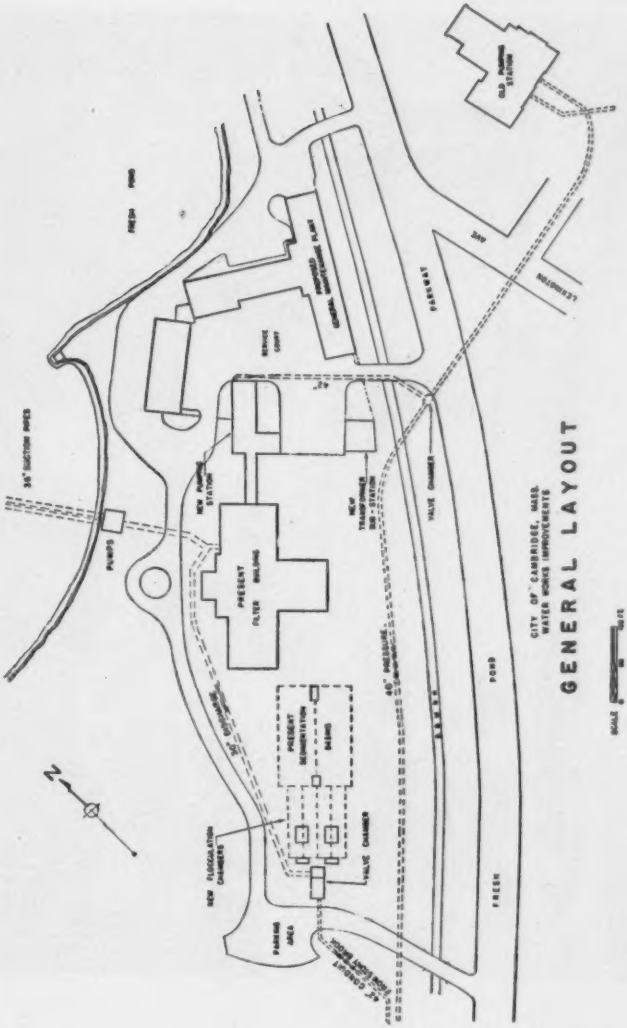

GENERAL LAYOUT
CITY OF CAMBRIDGE, MASS.
WATER WORKS IMPROVEMENTS
SCALE
FRESH POND
PRESENT FILTER BUILDING
NEW PUMP STATION
NEW TRANSFORMER SUB-STATION
PRESENT SEDIMENTATION BASIN
NEW FLOCCULATION CHAMBERS
VALVE CHAMBER
PUMPS
36" SUCTION PIPES
PARKWAY
OLD PUMPING STATION

FIG. 3.

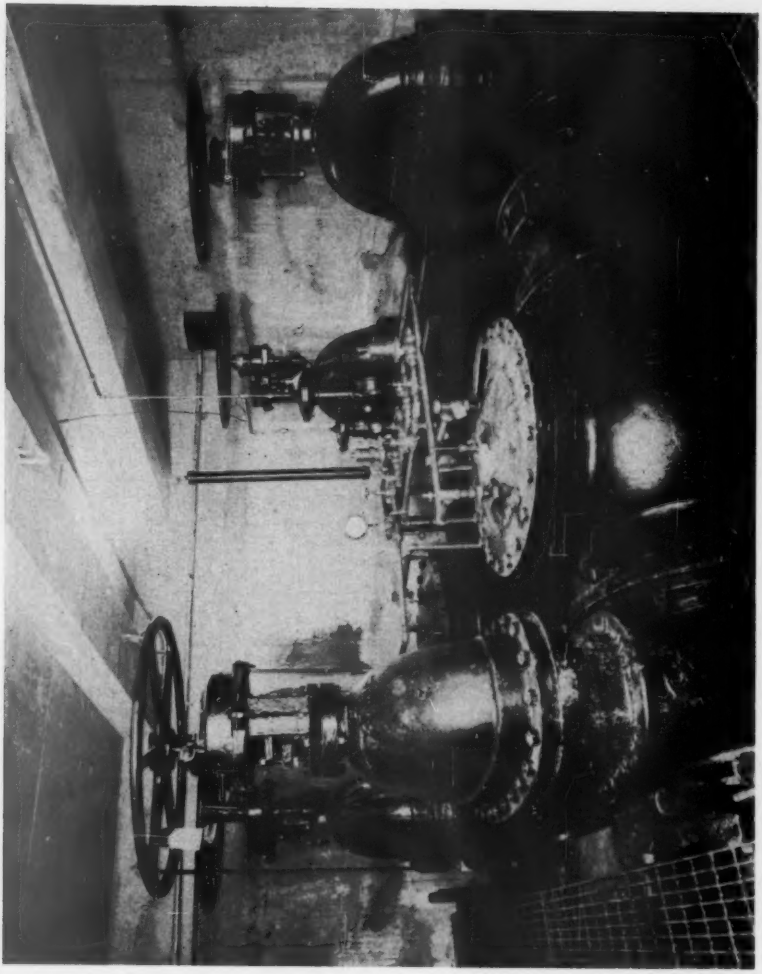


FIG. 5.—NORFOLK STREET CONNECTION WITH METROPOLITAN SYSTEM.

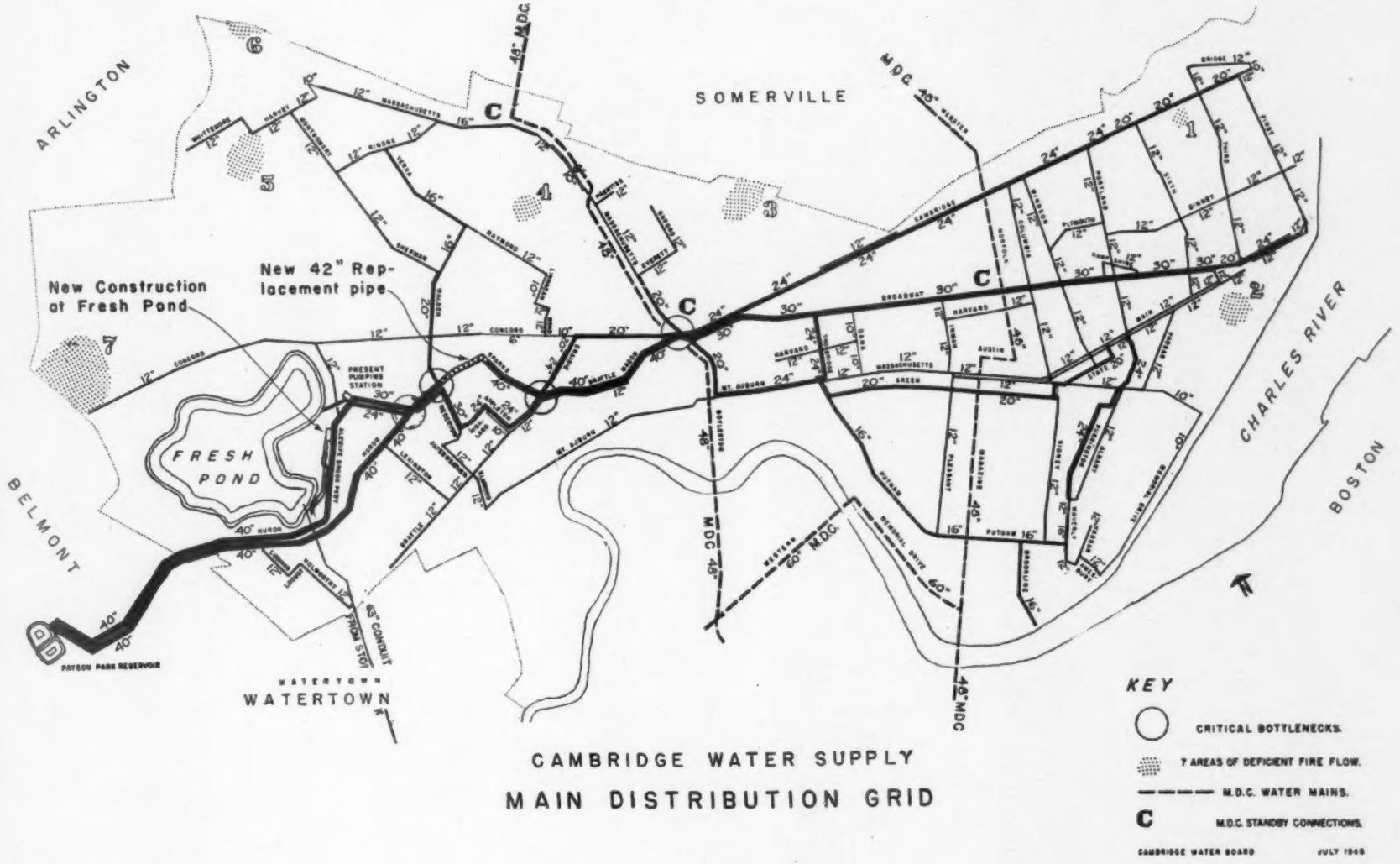

ARLINGTON
SOMERVILLE
BELMONT
BOSTON
CHARLES RIVER
WATERTOWN
New Construction at Fresh Pond
New 42" Replacement pipe
FRESH POND
PRESENT PUMPING STATION
PAYSON PARK RESERVOIR
63" CONDUIT FROM STOI
M.D.C.
CAMBRIDGE WATER SUPPLY
MAIN DISTRIBUTION GRID
KEY
CRITICAL BOTTLENECKS.
7 AREAS OF DEFICIENT FIRE FLOW.
M.D.C. WATER MAINS.
M.D.C. STANDBY CONNECTIONS.
CAMBRIDGE WATER BOARD
JULY 1908

FIG. 6.

amount of water was used here that treatment was required, an addition to the building would make this possible. Two of these connections were completed this summer and have been in operation during the work on the main distribution feeders.

Distribution System

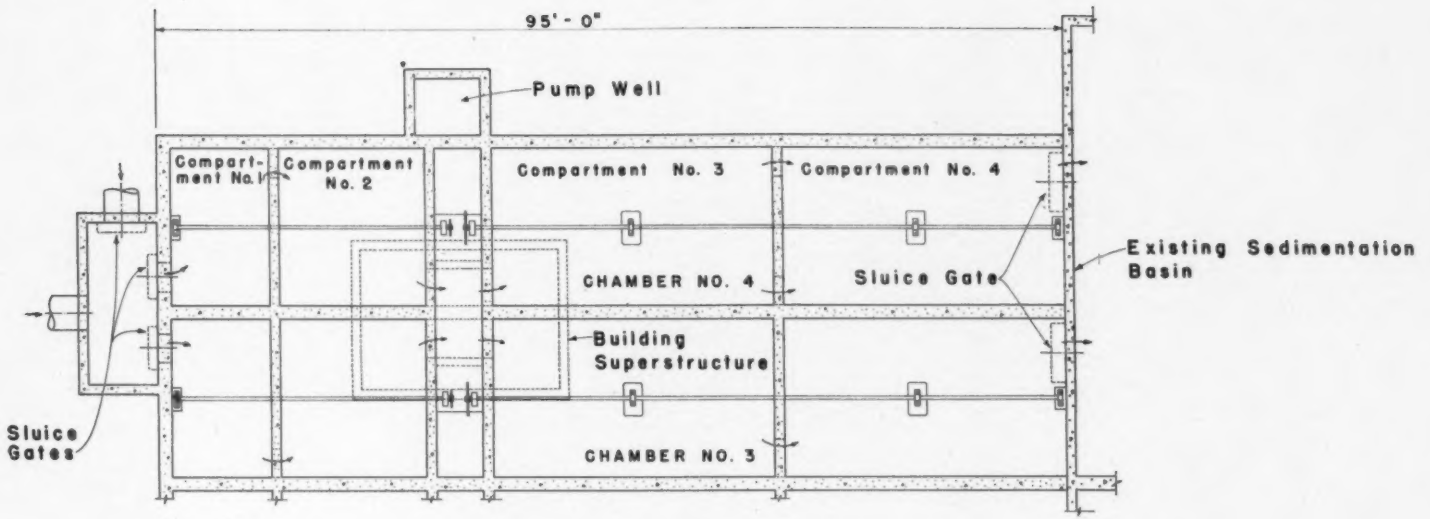
The consulting engineers' analysis of the distribution system was made in 1948, using in part the results of a survey made by the Pitometer Company in 1947. Their report showed that there were certain serious restrictive points or bottlenecks in the system, which with the increasing consumption and the decreasing carrying capacity of the pipes due to corrosion required improvement. These are shown on the map in Figure 6. Several methods of improvement were considered. One contemplated the use of elevated tanks, which was quickly eliminated on account of the cost. The two others required the cleaning and lining of some of the main feeders and the addition of certain lines to strengthen the parts of the system. Of these, one was based on making the emergency connections with the Metropolitan District Commission described above. The saving in cost of the latter was one of the factors leading to these connections. The report also recommended the adoption of a program of cleaning and lining the larger pipes in the future, as their age reduces their carrying capacity and as the consumption of water increases. In general this plan consisted of cleaning and lining now with cement all 40-inch lines, *i.e.*, the force-main leaders from the pumping station to the Payson Park distribution reservoir, and the main supply line running from Payson Park to the Cambridge Common—a total of about 22,000 ft. Part of the pipe which had been laid under the street-car line in Huron Ave., 1,050 ft in length, was badly pitted by electrolysis and is to be replaced with a new pre-stressed reinforced concrete pipe. This work is now nearly all completed. It was done after the Metropolitan District Commission connections were made, so that these could be used to supply the necessary water for the city. In addition, certain new pipes are to be laid in the northern part of the city to improve conditions there.

Filtration Plant

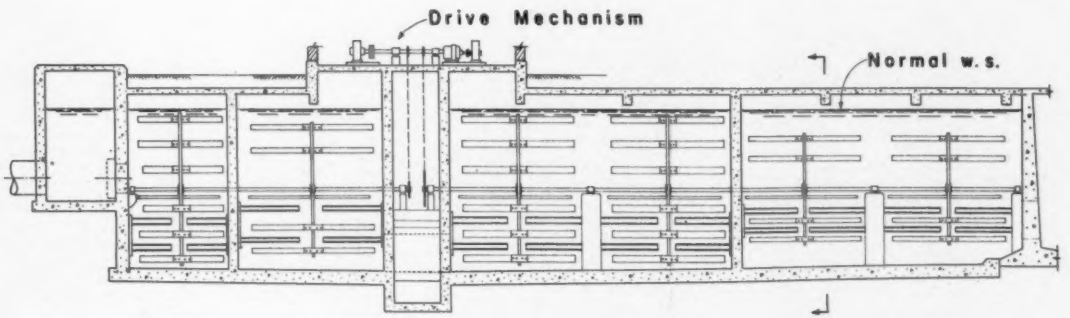
The present filtration plant has 16 mechanical filters with a normal capacity of 22.4 mgd. The present sedimentation tank is a double tank with a capacity of 1.5 mgd, which permits a detention period of only about 1½ hr of sedimentation at the full rate of filtration. In 1932 the construction of a new sedimentation basin was proposed, to be built at the north end of the filter plant, which would have a capacity of 375,000 gal and triple the area of the present tanks. This sedimentation plant, however, was never built. The present sedimentation system is now being changed as shown on Figure 7.

In order to provide more satisfactory sedimentation, flocculating chambers have been built ahead of the two present sedimentation basins. These are shown on Figure 8. There are two to each sedimentation basin and either can be used while the other is shut down, so that either sedimentation basin can be used alone. These flocculators are in effect in four parts—each part containing agitators of decreasing violence. It is expected that 45 minutes' mixture will suffice for a capacity of 22.4 mgd. The flocculating machinery is driven from a motor and the speeds can be adjusted as may be found necessary in actual practice. This flocculation chamber will materially reduce the amount of alum required for coagulating the sediment in the water.

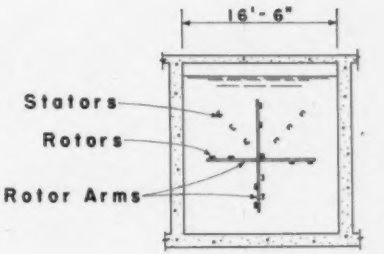
The additional sedimentation-basin capacity or area needed is obtained not by the construction of a new sedimentation basin as originally planned, but by dividing the present one into three stories —about three times the present area being thus obtained, as shown in Figures 9 and 10. This, of course, reduces the depth, but it is now known that the floor area is the important factor in sedimentation rather than depth. It is expected that, with the new flocculators operating at the rate of 22.4 mgd, these chambers will require cleaning about once a week. The amount of sediment and the volume of wash water from the basins will be greater than in the past, requiring a new pump of 5-mgd capacity. The wash water from the filters now goes into Fresh Pond, but the sedimentation waste is at present discharged into the sewer. This sewer has not a sufficient capacity to take the increased amount from the new basin and it is proposed for the present to discharge this also into Fresh Pond. This cannot,



HALF PLAN

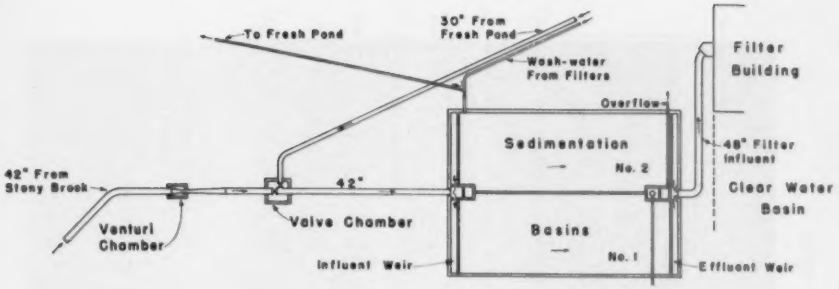


LONGITUDINAL SECTION

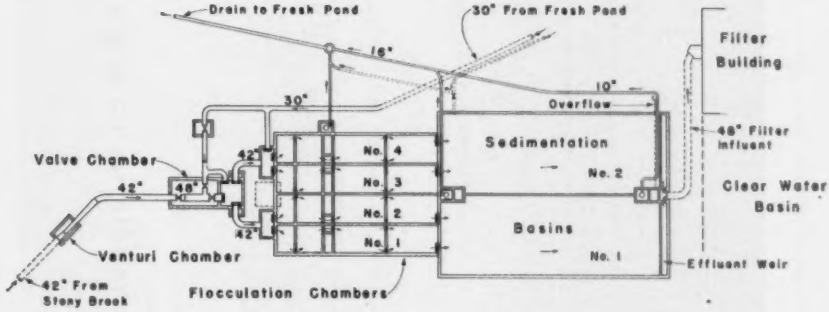


CROSS SECTION

FIG. 8.--NEW FLOCCULATION CHAMBERS



FORMER LAYOUT

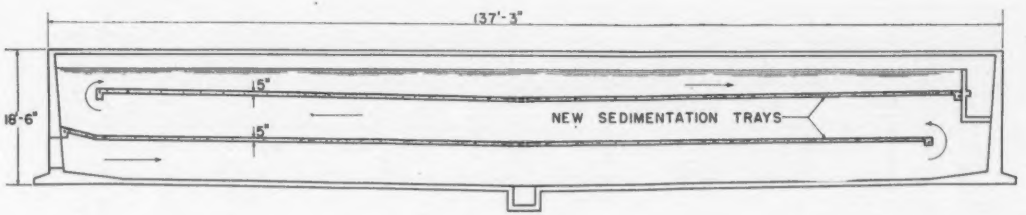


WITH NEW CONSTRUCTION

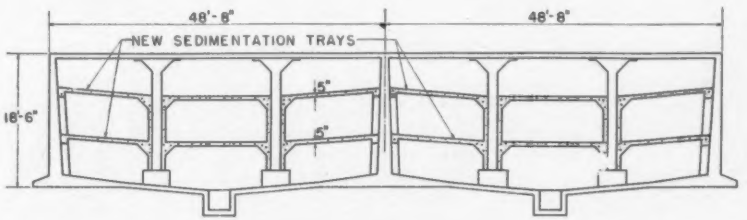
FIG. 7.--TREATMENT PLANT

however, be a permanent arrangement, as the sediment involved from this and the filters, amounting to about 7 mg per year, would eventually decrease the volume of storage in the pond too much. Several methods have been suggested to dispose of this waste water, but no decision has yet been made.

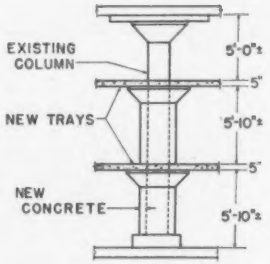
With the present arrangement of flocculating chambers, the new sedimentation basin and the present filters, it is estimated that the



LONGITUDINAL SECTION



CROSS SECTION



TYPICAL COLUMN DETAIL

FIG. 9.--ALTERATIONS TO SEDIMENTATION BASINS

FIG. 10.—CONSTRUCTION OF LOWER TRAY IN SEDIMENTATION BASIN.

capacity of the filters will be increased by 50%. With a present consumption of 16 mgd and possible maximum daily consumption of 24 mgd, this plant with improvements should be adequate far into the future. The capacity exceeds that of the conduits leading from Stony Brook.

In order to improve the existing poor arrangement for the feeding of lime into the water just prior to its chlorination, a further change was made in putting the lime apparatus into a new room between the present pumping station and the filtration plant—thus permitting the lime to be fed into the system after chlorination.

The effect of these improvements may be summed up as follows: (1) The present sedimentation system is too small, putting a very heavy load on the present filters and requiring a very much more rigorous schedule of use of Fresh Pond and Stony Brook water. This is due to the fact that Fresh Pond water requires less filtration than that from Stony Brook. With the new prefiltration treatment, there will be greater flexibility in the use of these two sources. (2) There will be a considerable alum saving, due to better flocculation. (3) There will be a saving at present in the reclaiming of the wash water now wasted. (4) There will be an increase in the capacity of the filter plant from the present 17½-22 mgd to 30 mgd, and (5) there will be better sanitary results and improved color, odor and taste—in other words, a supply of water to the city of much better quality.

High-Lift Pumping Station

The present steam pumping station has now the two operating pumps: the first a triple-expansion Levitt vertical pump of 20-mgd capacity, built in 1896. This is a very beautiful piece of machinery. It is still being operated as spare equipment. The other is a Worthington horizontal cross-compound pump of 20-mgd capacity, installed in 1928, which now pumps most of the water for the city. The necessity for the replacement of some of the boilers, the difficulty of getting firemen, and the high cost of fuel led to the investigation of a new source of pumping, although the Worthington pump is not worn out or obsolete and, with the connections with the Metropolitan supply, the city would not have to count upon the 55-year-old Levitt engine

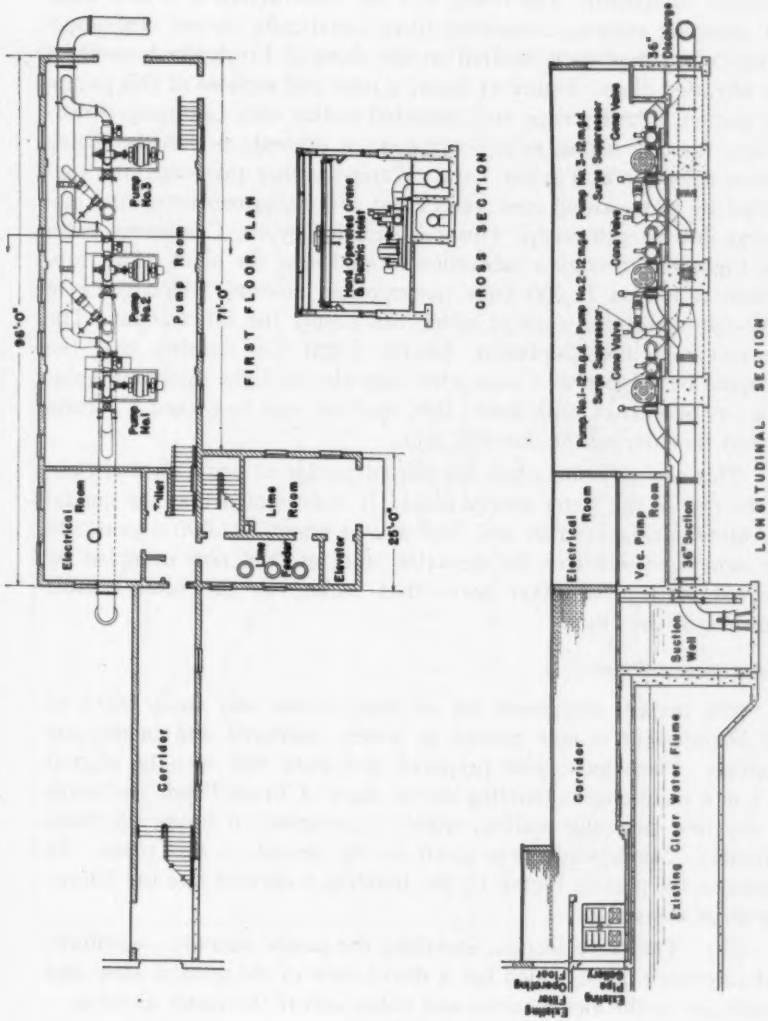


FIG. 11.--HIGH-LIFT PUMPING STATION

as spare equipment. The result was the construction of a new high-lift pumping station, containing three electrically driven centrifugal pumps of 12 mgd each, located on the shore of Fresh Pond, north of the filtration plant. Figure 11 shows a plan and sections of this pumping station. These pumps are connected so that they can pump directly into the city mains, as is being done at present, or into the distribution reservoir at Payson Park. Water-hammer pressures are controlled by slow-closing cone valves and surge suppressors on the discharge line of each pump. Power is supplied by the Cambridge Electric Light Co. through a substation located near the plant. This substation is fed on 11,000 volts underground circuits, which come in from two directions, each of which can supply the full amount. The contract with the Cambridge Electric Light Co. requires that the pumping be stopped at a time which the electric light company designates as periods of peak load—this, however, not to exceed a certain limited time during the day and year.

This new pumping plant has the advantage of being located close to the rest of the water-supply plant. It is estimated that the annual operating saving in labor and fuel will be about $22,000 a year and the new plant will free the desirable tract of land now occupied by the old station for other uses—thus adding to the total taxable property of the city.

Maintenance Plant

The present equipment for all maintenance and repair work of the Department is now housed in widely scattered and inadequate quarters. Plans have been prepared and work will soon be started on a new maintenance building on the shore of Fresh Pond, just north of the new pumping station, which is designed to house all these activities. Much study was given to the layout of this plant. As shown on the plan in Figure 12, the building is divided into the following main elements:

(1) The office section, including the public entrance, vestibule, and foreman's office, which has a direct view of the general shop and is adjacent to the locker rooms and toilets and to the meter division.

(2) The meter division—a self-contained unit, including shop,

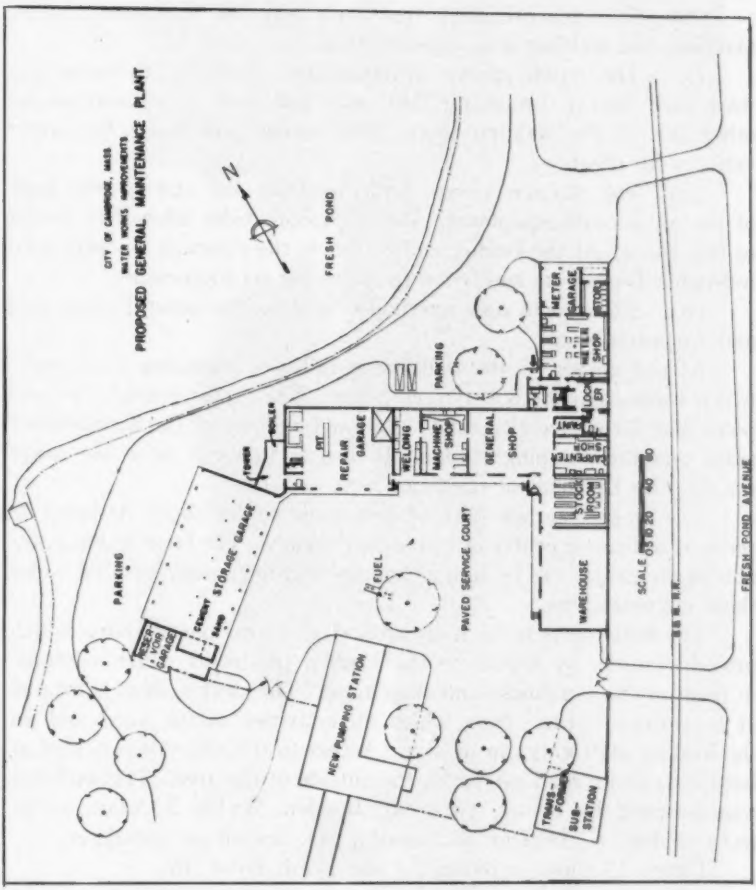

CITY OF CAMBRIDGE, MASS.
WATER WORKS IMPROVEMENTS
PROPOSED GENERAL MAINTENANCE PLANT
N
FRESH POND
PARKING
STORAGE GARAGE
TOWER
BOILER
PIT
REPAIR GARAGE
WELDING
MACHINE SHOP
GENERAL SHOP
PARKING
METER GARAGE
METER SHOP
LOCKER
STOCK ROOM
WAREHOUSE
FUEL
PAVED SERVICE COURT
NEW PUMPING STATION
TRANS-FORMER SUB-STATION
SCALE 0 10 20 40
B & M R.R.
FRESH POND AVENUE

FIG. 12.

storage and garage, planned to operate entirely independently of the other shops.

(3) The general shop area with separate carpentry, paint, machine, and welding shop adjacent to it.

(4) The repair garage with complete facilities, including pit, wash rack, and a storage for lubricants and parts, is located on the other side of the welding shop. This garage will house the larger vehicles at night.

(5) The storage garage with facilities for storing the bulk of the automobile equipment. Doors on both sides allow free access to this space. At the farther end of this is the reservoir division with independent quarters and separate spaces for its equipment.

(6) Stock room and warehouse next to the general shop area and carpenter shop.

At one corner of the building is a tower enclosing a chimney, which leads from the boiler room below. This tower provides a focal point and decorative element to the low buildings of the maintenance plant and the pumping station. It also is to serve as a fire tower for the Fire Department training.

The storage-garage part of this building has been designed to serve as a disaster center in case of emergency. The large space available in the garage can be used as housing and temporary hospital under these circumstances.

The building is to be built around a central paved court, which provides access by trucks to the loading platforms which continue in front of the warehouse and shop areas. The clerk's office is located at a strategic corner, from which all activities in the yard and on the loading platforms can be seen. Access to this court is provided at both ends and a road surrounds the outside of the area. This building was designed by Somes, Griswold, Boyden, Wylde & Ames, architects—Sidney S. Anthony of Augusta, Me., served as consultant.

Figure 13 shows a picture of the Fresh Pond site.

FIG. 13.—VIEW OF FILTRATION PLANT AT FRESH POND, SHOWING NEW PUMPING STATION AT RIGHT. (Photo by Ashton Studio).

FINANCE

The work was financed by appropriations divided as follows between funds from surplus and funds from the issue of 20-year bonds:

FINANCING—APPROPRIATIONS

	From surplus	*From 20-yr. bonds*	*Total*
Connections with MDC			
Connections, 1949	$120,000		
Additional	5,000		$125,000
	$125,000		$125,000
Distribution Plant			
Previous (remaining)	$125,000		$125,000
1950	92,000	$182,000	274,000
	$217,000	$182,000	$399,000
New Pumping Station			
Mar., 1950	$108,000	$222,000	$330,000
Additional	80,000		80,000
	$188,000	$222,000	$410,000
Filtration Plant			
Mar., 1950		$446,000	$446,000
Additional	$135,000		135,000
	$135,000	$446,000	$581,000
Maintenance Building			
1950	$ 51,000	$ 74,000	$125,000
Additional, 1951	185,000		185,000
	$236,000	$ 74,000	$310,000
Grand Total	$901,000	$924,000	$1,825,000

At the present time the three connections with the Metropolitan supply are completed. The pipe lining is nearly complete, and work on the filtration plant and pumping station is well along. Plans of the maintenance building are practically complete. The main contracts let up to the present time for construction and equipment are given on the list at the end of this paper.

Water Rates

For many years, Cambridge had a flat water rate of 10¢ per 100 cu ft—the lowest rate in the state. Since that rate was established the business has grown. From 1940 to 1949 consumption had increased from 12 to 15 mgd, the income from $519,200 to $690,700 and the expenses very much more—from $444,000 to $659,400. This increase in expenses was largely in the later years, with large increases in wages and materials. Under the original legislative act establishing the Cambridge Water System, its finances are kept entirely separate from the other departments of the city. This applies to its income, expenses and bonded debt. The department does not set up any depreciation reserve, so that all replacement and improvements come from the accumulated surplus of the department or from bonds. Under a recent act, there is a provision enabling the use by the city of any accumulated surplus in excess of $300,000 for other permanent capital purposes, provided it is approved by the Water Board. It became evident that if the Water Department was to earn sufficient surplus to take care of emergencies and to provide for the necessary replacements, a higher water rate would have to be charged. After careful studies of the best way to secure more income, it was decided to make a flat increase of 30%, raising the rate to 13¢. This was made effective on July 1, 1950. This rate is still a very low one for the domestic and other users of small quantities, but is not as low as the lowest parts of rates granted to very large users in some other Massachusetts cities.

Route 128

In the summer of 1950 the new Route 128 was built across the Stony Brook Reservoir on a high embankment. Two 12-ft square culverts were provided under the fill and excavation for the fill was taken from the bed of the reservoir, so that none of the storage capacity was lost by the construction of the road. This crossing is not far from the outlet and, in order to make sure that the excavation and construction, including the cofferdams for the culverts, did not rile the water so as to affect its usability in the filters, careful specifications were drawn covering the fill and the cofferdam, requiring a graded fill with large stone on the reservoir side, grading to fine material on the inside, with the provision that no clay or fine material

should be dumped into the water on the outside of the cofferdam. The Public Works Department and its consulting engineer, Thomas Worcester, Inc., and the contractor, J. F. Fitzgerald Construction Co., were extremely coöperative in the design and construction of this work, so that no detriment was suffered in Cambridge's water supply. Some fill was also required in one corner at the Hobbs Brook Reservoir, but this was so far from the intake that no special precautions were required, except rip-rap on the embankment.

* * *

When the plans for this program started in the spring of 1947, the Board had the benefit of the experience of the late Timothy W. Good, superintendent since 1918, who retired in 1947, becoming a member of the Board until 1950. His place was taken by the present superintendent, William H. McGinness, who stepped into his new work at this time of extraordinary activity and expansion. The Board has been fortunate in having the counsel and coöperation of Col. John B. Atkinson, the city manager, in the working-out of this whole program. The interest of Mayor Edward A. Crane has been of value, as has that of other members of the city council, which has approved the program and appropriated the necessary money.

LIST OF PRINCIPAL CONTRACTORS ON CAMBRIDGE WORK

Contract	Name of contractor
No. 1—Flocculation and Sedimentation Facilities	R. Zoppo Company
No. 2—High-Lift Pumping Station	R. Zoppo Company
No. 3—Connections to the Metropolitan System	R. Zoppo Company
No. 4—Cleaning and Lining 40-in. Steel Mains	Pittsburgh Pipe Cleaner Co.
No. 5—New 42-in. Water Mains	Williams Bros. Construction Co.
Furnishing Three 12-mgd Pumps, Motors, and Station Switchboard	Turbine Equipment Co. of New England
Furnishing Flocculation Equipment	Link-Belt Co.
Venturi Meters and Controls at Metropolitan Connections	Builders-Providence, Inc.
Pressure-Reducing and Flow-Control Valves at Metropolitan Connections	Ross Valve Mfg. Co., Inc.

LIMITATIONS OF STANDARD BACTERIOLOGIC METHODS IN EVALUATING SANITARY QUALITY OF WATER

BY F. WELLINGTON GILCREAS*

[*Read September 12, 1951.*]

The first edition of *Standard Methods of Water Analysis* (1) was published by the American Public Health Association in 1905. However, for ten years prior to that, studies had been undertaken to resolve the chaotic condition which existed in examinations of water to determine its potability. In fact, in 1895, a committee was appointed to consider this problem and the first edition was the fruit of their activities. It is interesting to note that in the footnotes to the reports of the committee and in the preface to the first printed volume (1), both groups stated that the methods they were recommending were provisional only and were being published in the hope they would direct the attention of individuals in the field to the urgent need for further research in the development of precise and acceptable procedures. The early committee freely admitted that there might be other and better methods than those selected, but said that it had tried to recommend those most acceptable in the present state of their knowledge. In the preface to the first edition, the then Standard Methods Committee pointed out that they were well aware that methods proposed for use in one area would not necessarily be equally satisfactory in others. The reports also stressed the importance of the bacteriologic examination, which, of course, was of much more recent development than the chemical methods of analysis which for perhaps fifty years previously had been used as the sole criterion of the sanitary quality of water.

All of these statements have a very familiar sound at the present time, when, after a lapse of forty-six years, the 10th edition of *Standard Methods for the Examination of Water and Sewage* is in preparation. The methods are still provisional; they still need study;

*Assistant Director, Division of Laboratories and Research, State Department of Health, Albany, N. Y.

it is still hoped that they will be used so that the work of all laboratories in the country will be on the same basis, and that they will stimulate further research in the development of standard procedures. The limitations of these methods are well recognized, but they are the best procedures available today.

In accordance with the statement in the preface to the first edition, I should like to confine attention to the bacteriologic procedures for the examination of water, omitting any discussion of chemical methods of analysis, which, incidentally, have also grown in importance and significance during the past fifty years that we have had *Standard Methods*.

In the first edition, as will be true in the 10th, the foundation of the bacteriologic examination of water is the detection and enumeration of intestinal bacteria. They were the principal methods studied by the original committee and are the ones particularly stressed in the first edition. So far as I have been able to determine, *Bacterium coli* was first used as an indicator of pollution in 1890, when Dr. Theobald Smith was engaged in a study of the pollution of the Mohawk River in New York State (2). At this time he developed his famous Smith fermentation tube and the methods for isolating *B. coli*, as he called it, from water, and also established the quantitative significance of that microörganism as an indicator of water quality. From that time on, the presence of *B. coli* has remained the principal criterion for determining the bacteriologic contamination of water. This choice originally was based upon the fact that most diseases, as understood at that time to be transmitted by water, were the intestinal diseases of human beings and consequently the pathogenic microörganisms were known to be accompanied by *B. coli*.

In the early studies the definition for *B. coli* differed from our conception of it today. The presence of *B. coli* was not considered completely demonstrated unless the microörganism as isolated proved to be a non-spore-forming bacillus, small and quite thick in structure, motile, and one that did not liquefy gelatin but fermented lactose broth with the formation of carbon dioxide, coagulated milk with the production of gas in 48 hours, produced indol from peptone solution and reduced nitrates to nitrites. This definition was continued during

the first two editions, but our ideas as to what constitutes *B. coli* have been modified until now the 9th edition defines the coliform group as including all aerobic and facultative anaerobic Gram-negative non-spore-forming bacilli which ferment lactose with gas formation within 48 hours at 35°C. This definition at the present time is the subject of some criticism—mainly to the effect that it is too inclusive and thus that the microörganisms conforming to the definition are not necessarily indicative of significant contamination of water. However, much further and more intensive research is needed before this definition of the coliform group can be changed to yield a more specific indicator organism or group of organisms. In the 10th edition the definition of the coliform group will be the same as in the 9th.

The microörganisms known as *B. coli* in the first five editions became the coli-aerogenes group in the 6th and are described as the coliform group in the 9th and 10th editions. In conformance with the instructions by the early authors of *Standard Methods,* the procedures for the detection of *B. coli,* the coli-aerogenes group, and the coliform group have been widely studied. Each edition has produced some change in technic.

Apparently, the earliest culture medium was a phenol broth, a nutrient lactose broth containing 0.5% of phenol. Thus, the use of inhibitive materials in the culture medium was one of the first technics investigated. Many changes in this type of medium have been studied, until use of lactose broth without inhibitive agents was firmly established as standard about ten years ago. The elimination of selective media for the primary fermentation test was found necessary because the inhibitory effect was visited upon attenuated strains of coliform bacteria, significant as indicators of contamination, as well as upon non-coliform strains. Gradually, the use of confirmatory tests supplementary to the presumptive tests was developed and has continued, although with many variations in media compositions over the years.

The one great weakness of the bacteriologic examination of water has been the time required for the test, which makes the results of *post mortem* value only. It is impossible to determine whether the water has been contaminated or not until long after it has been con-

sumed. Every attempt has been made to shorten the technic. The completed test, which in the beginning was extremely complicated and included gelatin liquefaction requiring 14 days, coagulation of milk, and other tests, was simplified until the custom developed of relying upon the confirmed test only. This change was based upon a study of an earlier Standard Methods Committee, which found that brilliant-green lactose bile broth could, with acceptable precision, be used as confirmatory medium to indicate the presence of coliform bacteria in the portion of water under examination. For the 10th edition, the committee tried to simplify this procedure further, but no information is available to show that a selective medium for the presumptive test can be used to indicate the presence or absence of coliform bacteria with satisfactory reliability. The use of confirmatory media must be continued.

As a result of studies of lauryl sulfate tryptose broth, which was permitted by the 9th edition for use with certain types of water, this medium will be recommended as an alternate for beef-extract lactose broth in the presumptive test, but positive presumptive tubes must be confirmed by subsequent inoculation into brilliant-green lactose bile broth or other confirmatory media. This change should simplify the technic although it does not reduce the time required. It will eliminate many non-coliform microörganisms which ferment lactose and produce gas in the presumptive test and, therefore, save time otherwise spent on confirmation. Yet the production of gas in a primary lauryl sulfate tryptose broth presumptive test cannot be considered conclusive evidence that the microörganisms are true members of the coliform group.

The coliform group is an indicator only of pollution by the intestinal discharges of warm-blooded animals. It does not reveal the presence or absence of specific pathogenic bacteria nor do current methods differentiate between those members of the coliform group found in human excrement and those found in animal fecal matter. With the decrease of enteric infections in the population, the possibility of polluted water's carrying these pathogenic bacteria lessens day by day. However, as the coliform test indicates the presence of sewage in water supplies, the results remain of paramount significance

in determining the sanitary quality of the water. In spite of the agitation about human and animal fecal strains of coliform bacteria, the differentiation is of no practical significance. Water containing intestinal discharges from warm-blooded animals, whether domestic, wild, or semi-aquatic, is of no better esthetic quality than water containing discharges from human beings. There is some evidence that animal discharges may contain infective agents of ailments other than typhoid or dysentery. Possibly many of our so-called gastro-intestinal outbreaks are caused by such animal wastes.

The significance of the aerogenes section of the coliform group also merits attention. The established routine test does not differentiate it from the coli section and yet the sources of the two are quite different. Special methods for such differentiation are included in *Standard Methods,* but their routine use would delay even further completion of the laboratory work on a given sample. It would seem that the *Aerobacter aerogenes* microörganisms do not belong in a potable water and thus their presence is an indication of pollution from some source. The development of new differential tests for the coli and aerogenes sections would not aid in evaluating the sanitary quality of water. For appraising the quality of public water supplies—treated or untreated—the coliform group is useful even though results are not obtained as quickly as desirable. The results of bacteriologic examinations continue to be essential in making a final judgment on the effectiveness of any type of water treatment.

The presently established bacteriologic tests do not provide for the detection and enumeration of microörganisms which ferment lactose slowly, producing gas only after 72 or 96 hours or even longer. Yet statements are made that their presence renders water non-potable. Non-lactose-fermenting bacteria have been accused of producing illnesses in consumers of water in which they are present and would not be detected by any standard technics. However, if these types of bacteria reach the water through sewage pollution, the coliform test will detect that pollution and indicate that the water is not suitable for use. Conclusive data are lacking that significant numbers of pathogenic bacteria survive longer in water than the coliform group. Yet further study of that particular phase of water bacteriology is well warranted.

The need for a quantitative method for the measurement of pollution of water was early recognized. The first directions for the test for *B. coli* or the coli-aerogenes group required the inoculation into a liquid culture medium of a graded series of volumes of the sample—usually multiples and sub-multiples of one cubic centimeter. This procedure was followed by the recommended use of a multiple number of portions of each volume of the sample tested. The range of volumes and the number of portions of each is determined by the analyst and the use to be made of the laboratory results. In general, 10 ml is considered the critical volume, with a series of decimal multiples of 10 ml to provide an estimate of the density of the coliform population and thus of the concentration of pollution in the water under examination.

Various methods of expressing the coliform densities by use of a numerical index have been proposed, used for a time and discarded. The most recent is the M. P. N. index, which has received general acceptance. This is the number of coliform microörganisms which more probably than any other number would yield the observed laboratory results. Obviously, such an index has limitations as a measure of pollution. Too often the index is considered and used as a precise census of the numbers of the coliform group, or the significance of an index per 100 ml is not appreciated, but is interpreted on the basis of the more commonly used 1-ml volume, with resulting confusion. However, familiarity with the M. P. N. index, gained by its continued use, has enhanced its value as a measure of pollution.

In the examination of waters from swimming pools or bathing areas the coliform group is of little importance, since the significant bacterial contamination of the water may not be intestinal in origin but associated with other body discharges. There has been considerable agitation in the recent past to stimulate further search for more satisfactory indicator microörganisms of the quality of bathing waters. Fecal streptococci have been investigated and studies made of technical procedures for their isolation and enumeration (3). Unfortunately, the results so far do not warrant including these methods in the 10th edition of *Standard Methods*. Too little

is known of the quantitative significance of this class of microörganism in water. Not only the fecal streptococci but other streptococci in water may be of significance, especially in swimming pools.

Present trends in bacteriology emphasize the significance of viruses in public health and much is said about the ability of virus to survive in water, even in treated water. The virus of poliomyelitis has been isolated from sewage and heavily contaminated water, and the theory has been advanced that water may be one medium of transmitting the disease (4, 5). All of this progress in virology needs to be associated with the general field of sanitation, particularly to problems of water examination, both polluted and those we consider relatively uncontaminated. However, methods for isolating virus from water are unreliable. The quantitative significance of virus in water is unknown. A vast field of research is opening up and, although the 10th edition of *Standard Methods* cannot recognize the possibility of virus infections being carried by water, nevertheless there is no question but that research in sanitary science in the future will be directed into this avenue, as well as toward studies for improved methods for detection of the coliform group, and the detection and sanitary significance of other bacteria such as the streptococci.

For the early years of *Standard Methods* the enumeration of miscellaneous bacteria in water by means of a plate count at 37°C. and at 20°C. was considered of great importance in evaluating the sanitary quality and thus pollution of water. In fact, at one time a standard plate count in excess of 100 per ml was considered adequate basis for condemning the potability of a water. Advancing knowledge in sanitation and in bacteriology resulted in de-emphasizing the significance of the plate count, and first the 20°C. count was dropped and at present the trend is to eliminate the 37°C. count (now made at 35°C.). However, the latter is still useful as a supplementary index of water quality, particularly in evaluating the results of filtration and disinfection treatment. Thus, the technic modified as to temperature of incubation (35°C.) and medium (tryptone extract agar) will be retained in the forthcoming edition of *Standard Methods*.

Standard Methods has always been concerned only with the

detection and enumeration of bacteria indicative of sewage pollution. And yet other bacterial microörganisms can be present in water and create serious nuisance conditions in the collection and distribution of water supplies. Methods for the detection of bacterial forms which produce slime formations on water-works structures and aid in corrosion and incrustation of mains would be helpful. In response to numerous requests, a new section, entitled "Nuisance Bacteria" is to be included in the 10th edition. Unfortunately, too few data are available concerning these so-called higher bacteria, and quantitative methods for their detection and enumeration are not well established. The new section will be tentative only, but it is hoped that it will stimulate research into what may prove to be an important field of sanitary bacteriology.

The validity of examinations of water is predicated upon the integrity of the sample. A criticism frequently made of previous editions is the unrealistic requirement regarding the time that can be permitted to elapse between collection and bacteriologic examination of samples. The first edition recommended that samples for bacteriologic examination be received at the laboratory within six hours. The 9th edition requires that the time interval between the collection and the start of the analysis shall not be more than six hours, except that for waters known to be relatively uncontaminated it may be twelve hours. The recommendation is made that, for this interval, the temperature of the sample shall be kept between 6 and 10°C. For the routine sampling of water supplies, strict adherence to these recommendations is almost impossible and the general trend has been to permit a much longer period to elapse, in many cases without refrigeration, between collection and examination. In some areas of the country the practice has developed of shipping samples of water by mail without refrigeration and examining them when 24 or even 36 hours have elapsed. This is a deviation from *Standard Methods* and the results of the examinations must be interpreted with allowance for this evasion. However, there seem to be no data available to explain why six or twelve hours were better than twenty-four hours, or as permissible as thirty minutes or one hour. It seemed that the time had come for a complete investigation to support a

fundamental requirement regarding the time permitted to elapse between collection and examination of samples of water. The Committee on Standard Methods organized a study to determine the quantitative changes in the bacterial flora, particularly as represented by the coliform group, during periods of refrigerated and unrefrigerated storage from a zero time to 30 hours. The results showed some variations with different types of waters. With Lake Michigan water it was found that changes over 24 hours in numbers of coliform bacteria were related to the original temperature of the water rather than to the temperature or time of storage. In other areas this effect was not noticed.

In the examination of 36 samples in the laboratories of the New York State Department of Health, even with refrigerated storage for six hours, there were marked changes in the density of coliform bacteria, and some of these paralleled closely the changes in a duplicate sample stored without refrigeration for the same period. In general, however, the results of our share of the larger study indicated that there was little significant change in the density of coliform microörganisms in samples of water of low original coliform density, represented by a M. P. N. index of 5 to 240, during a 24-hour unrefrigerated as compared with a 24-hour refrigerated storage period.

The results of the over-all investigation cannot be considered conclusive and the committee is continuing it. No change in the requirements following the collection of samples will be incorporated in the 10th edition. The coöperation of everyone is needed to determine the basic factors which govern the quantitative changes of bacteria on storage, in order that a more rational requirement may be established, and in order that we may have a sound basis for interpreting the results of bacteriologic examinations of samples which have undergone periods of storage between collection and examination, as compared with those which are examined immediately after collection.

The standard procedures for the examination of water are not finally established; they have definite limitations, which must be understood thoroughly. These are limitations of technics, culture media, or the influence of environment on the microörganisms or

group of microörganisms selected as an indicator of contamination.

Perhaps an important limitation is the significance of the coliform group as indicating contamination of water by sewage or intestinal discharges, frequently unaccompanied by pathogenic microörganisms. The aim at present of the recommended standard laboratory procedures is to assure that water is of acceptable esthetic quality, with the expectation that it will then be safe.

Our ideas concerning the interpretation of water examinations have kept pace with investigation of laboratory methods, but further research on problems of interpretation would be valuable. The results of laboratory examinations, particularly of bacteriologic examinations, provide a very delicate and precise measure of the quality of the water and of the accomplishment of treatment procedures more accurate than can be made by any mechanical gauges or other equipment. Their value is greatly reduced if the individuals who interpret the results are not thoroughly acquainted with their limitations. It follows that the engineers and other administrative personnel who use the results furnished by the laboratory must be trained in ways to read and apply these very useful measuring devices.

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THE WATER-WORKS LABORATORY IN CIVIL DEFENSE

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Within recent months Civil Defense planning has received considerable publicity, much of which has been of a critical nature. In many instances, that criticism has resulted from the indifference encountered by those engaged in Civil Defense planning or because those workers felt that necessary information about the problems to be faced was being withheld or that there was no advice on how to meet the problems that had been posed. One need not elaborate upon this state of mind, because I am certain we are all familiar with it. I am also sure that each of those among you who have had an opportunity to work upon some portion of a Civil Defense program has, at some point, come to the realization that progress was being made; that it was being made at local levels, and that it was being made without too much guidance from federal and state levels.

I should like to discuss today a plan relating to Civil Defense which can be participated in by each water-works laboratory—including the operator with only the most meager of laboratory facilities. The ideas suggested in this plan are not original and I claim no credit for them. They do, however, appear to be practical suggestions, which can well be integrated into the public water-supply portions of Civil Defense programs. Nearly all of the suggestions and information which I wish to present to you were obtained from courses given at the United States Public Health Service's Environmental Health Center in Cincinnati, Ohio, or from publications prepared there.

When children first start to school, they gradually learn that their ability to absorb the facts—and non-facts—which are presented to them is measured by their ability to answer questions which are posed to them. They gradually come to feel that *the correct* answer exists for all questions—that the answer to any question must be

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positive or negative, or black or white. It frequently comes as a shock to them, usually during the early college years, that a great grey zone of answers exists in which the answer is neither "yes" nor "no"; neither black nor white. Those of you who have served in the armed forces know that there is never "the solution" to a military problem, but only "a solution." It is with such thinking that we must approach Civil Defense planning. It is with this type of thinking that I wish you to consider the suggestions to be offered to you relating to the detection of possible contamination in a water supply.

What is the potential danger which we might face in case of enemy attack? During the last war—and by "last war" I mean World War II—the range of enemy aircraft and its carrying power in terms of potential destruction was such that the continental United States could be reasonably considered as immune from any attack, except perhaps nuisance raids. No extensive all-out attacks were envisioned, and it was therefore necessary to plan against covert attacks in the form of sabotage or against overt acts in the form of limited raids by enemy aircraft or by enemy naval vessels. Since that time, several things have occurred which change the outlook with respect to possible attack against the continental United States:

1. The range of aircraft has increased enormously.
2. The havoc in terms of destruction which can be carried by an aircraft has increased enormously. This is perfectly obvious when we realize that the destructive power of an atom bomb weighing only a few pounds is equivalent to 20,000 tons of T.N.T.
3. The toxicity of chemical weapons has so increased that the amount which can be carried by an airplane and still produce casualties in more than nuisance amounts is a matter which cannot be overlooked.

The primary objective of a military commander is to defeat the enemy. How he does it and whether or not he does it will depend upon his skill in the use of the weapons at his command. It must always be assumed that the weapons of the enemy are of equal potential with our own, that the enemy is equally skillful in the use of those weapons, and that he will not hesitate to use any or all of them in such a manner as will accrue to his own advantage.

Experience in warfare has indicated that, generally speaking, a

combined use of weapons is more effective than a single weapon. For example, during the last war, high explosives were combined with incendiary bombs with telling effect. There seems little reason to doubt that a combination of weapons will be used again. It also seems unlikely that a single atom bomb will be used or that a single location will be attacked, because of the greater damage and greater confusion which would result from the use of combined weapons upon multiple localities. The picture which has been painted by persons who have given this matter consideration is one of a surprise attack, with combined weapons, against several targets in the United States, resulting in extensive physical destruction, fires and casualties numbering ten to twenty million. Such an attack would undoubtedly result in indescribable confusion. Undoubtedly the first overt act in the next war will be an attempted crippling blow to the industrial potential in this country.

Plans were made during the last war by water-works officials to combat attacks which might result in physical destruction of water-works systems, and those plans are being revised and considered anew. As a supplement to such plans, the water-works laboratory can serve in the overall picture of Civil Defense by aiding in the detection, and possibly prevention, of covert acts of warfare. Such covert acts would be those of sabotage and especially those acts of sabotage which are aimed at the impairment of water quality. Acts of sabotage may be aimed at impairment of potability, at interference with industrial processes through impairment of water quality, interference with water distribution to prevent fire fighting, or any other act against the water system which would interfere with the general economy of the community.

What are the possibilities? Let us reconsider the water contaminants which were available in 1941 and also those which have become available since 1941. The first group to consider is the chemical poisons, such as cyanide, arsenic and similar poisons. In general, the possibilities of the use of such agents in more than a limited manner seem remote. The amount of such materials which would be necessary to contaminate an entire water supply sufficiently to produce casualties seems to be beyond the realm of physical

possibilities. Even with hydrogen cyanide, a material which is highly toxic, the fatal dosage for man is given as 0.7 to 3.5 milligrams per kilogram of body weight. This means that a 150-pound man would require 70 to 250 milligrams to produce a fatal dose. A fatal dose in even a liter of water would require a concentration in excess of at least 70 ppm, or nearly 600 lb of chemicals—a quarter of a ton—per million gallons of water. The difficulty, yes, even impracticability, of contaminating an entire water supply with such a poison is readily apparent.

One of the chemicals which was developed during the last war and which was considered as a water contaminant is the nitrogen mustard war gas. This chemical is highly toxic, its toxicity being of the order of two milligrams per kilogram of body weight. This toxicity is comparable with that of the hydrogen cyanide and approximately 150 milligrams of the material would be required to produce death in seven days in 50% of the cases. Even with this material, large amounts would have to be added in order to contaminate entirely a large water supply. The nitrogen mustard is slowly hydrolyzed and the products of hydrolysis remain toxic as the chemical is hydrolyzed. It is for this reason that nitrogen mustard gave promise as a water contaminant.

Another group of chemicals which was considered as a possible water contaminant is the fluoroacetates. One commonly known compound of this group is the compound 1080. The material has no taste or odor, is highly toxic, and is slowly hydrolyzed in water (25% in 60 hours). Increased temperature in the presence of alkalies speeds the hydrolysis. The toxicity of this compound is on the order of 0.5 to 2 mg per kg of body weight.

Still another development in the field of chemical warfare is the organic phosphates, sometimes called nerve gases. The best-known chemical of this type is parathion, a compound which is used commercially as an insecticide. The toxicity of parathion is on the order of 1 mg or less per kg of body weight. The organic phosphates represent the most toxic chemicals developed during World War II. They are also the most specific enzyme inhibitors yet prepared. One of these compounds, diisopropylfluophosphate, has been used as a basis of

comparison in the study of toxicity of organic phosphates and has a toxicity on the order of 1 mg or less per kilo of body weight. The di-esters of fluophosphoric acid are highly toxic when inhaled, producing a quick knock-out comparable to hydrogen cyanide. A concentration of 0.44 mg per liter (about 1 part in 2000) will kill 50% of mice exposed to this concentration in 10 minutes. The poisoning may take place by inhalation, by ingestion through the alimentary tract or by absorption through the skin. The symptoms are immediate and are the same in man and animals. They occur within a matter of minutes. An immediate pin-point restriction of the eye occurs, followed by possible discharges from the eyes, ears or nose, nausea, bronchial constriction or spasms and convulsions. In high doses, death may even occur in a few seconds. The toxicity of some of these compounds is higher than phosgene. One of these chemicals—Tabun—which is known to have been produced in Germany, is said to be five times as toxic as diisopropylfluophosphate. Another compound of this type—Sarin—is said to be 20 times as toxic. With compounds of this nature, we are dealing with materials so poisonous that the possibility of contaminating an entire water supply becomes more practical than heretofore, although even with these poisons 50 to 100 lb, perhaps even up to 500 lb, may be required per mil gal of water.

The possibility of the use of agents such as botulinus toxin and paralytic shellfish toxin should not be overlooked. Again, however, even though the toxin itself is an extremely toxic agent, it must be grown in a food material and possibly could not be sufficiently concentrated to represent an effective weapon.

Biological agents would seem to lend themselves well to covert attacks of warfare, especially against water supplies. In considering water as a carrier for biological warfare agents, one must consider that about one-half per cent of the water delivered in any one day is used for drinking purposes and also that there are many days' storage in the reservoir, so that complete contamination of the reservoir becomes a problem requiring an enormous amount of the contaminating agent. In addition, water treatment and the natural factors, such as hydrolysis, temperature, sunlight, etc., will all work to make

this type of agent less effective. The greatest danger would seem to lie in the planting of a biological agent in a small area of a community by deliberately contaminating a portion of the distribution system.

This could be accomplished by pumping the agent into the system under pressure. Short of carrying an excessive chlorine residual throughout the entire system, it is impossible to protect against such acts. Such a procedure will also represent an effective way of distributing a chemical agent. Radioactive isotopes could also be distributed into a portion of a system in a similar manner. This latter means of contaminating a water supply is insidious, because of the slow, delayed action of the isotopes on the human animal. It would seem doubtful whether an enemy agent would choose to use such a weapon, because of the lack of immediate results. Rather, he would be seeking a more effective means of producing casualties within a determinable length of time. This could be more easily accomplished with either the chemical or the biological agents.

Plan for Water Laboratories

So far I have discussed only the possibilities of what might be done to contaminate a water supply. The question is, "How to detect or prevent such action?" It is not necessary to dwell at length upon preventive measures. Much consideration has been given to physical methods of protection. Fences, guards, locked buildings, etc., are all practical physical measures. Any measure which tends to make it difficult for an unauthorized person to gain access to a point where he might contaminate the treated water or even the untreated water represents a physical measure of protection.

However, the water-works laboratory can and should offer a second line of defense in case of a breakdown in the measures of physical protection. Planning for such action is a proper endeavor for a water-works laboratory in connection with Civil Defense activities.

Such efforts on the part of water-works personnel may to a very great extent prevent acts of sabotage against water supplies. While it is impossible for most water-plant laboratories to make a complete

analysis of water samples for the various chemical warfare agents or for biological warfare agents, it is possible to establish screen tests which will give some assurance of the safety of the water or to indicate that further investigations are immediately needed. Let us consider some of the agents which might be added to a water supply either as an act of sabotage or as a result of overt acts of warfare. The following groupings are those essentially of the U. S. P. H. S. Stream Pollution Investigating Station in a pamphlet called "Data on Chemical Warfare Agents."

Group I

Crude oil, fish oil, chemical smoke mixtures and agents which, while they may produce a non-potable water, will not produce a toxic one. Such substances would be readily detected by odor or taste.

Group II

In group II are agents producing a turbid water, which is non-toxic after the removal of the turbidity. This group contains Adamsite, diphenylchlorarsine and diphenylcyanoarsine. Turbidity would be the first sign of such agents.

Group III

The Public Health Service group III contains substances such as phosgene which, while very toxic in itself, will not produce a toxic water even though it is present in fairly high concentration. Such substances would certainly be present in the water supply only by accident or as a result of an incidental act of warfare. Immediate detection of such substances is of lesser importance. Changes in pH or alkalinity may result from the hydrolysis of such compounds.

Group IV

In group IV can be placed more poisonous chemical-warfare agents, such as chloropicrin, mustard gas, nitrogen mustard, Lewisite, ethyldichlorarsine, the fluoroacetates, the organic phosphates and possibly biological warfare agents, such as pathogenic bacteria and toxins. All of these are organic compounds and, if present in more than minute amounts, could affect chlorine demand, oxygen consumed and possibly other of the screen tests.

Group V

Group V will consist of agents which might be used for deliberate contamination, such as arsenic compounds, cyanides, heavy metal salts and alkaloids. We should also include again the biological warfare agents. Odor, turbidity, chlorine demand and oxygen consumed are tests which might be affected by such agents. The organic compound, biological-warfare agents will affect oxygen-consumed and chlorine-demand tests. Cyanide, if present in more than minute amounts, will produce a noticeable odor. Soluble arsenic compounds, heavy metal salts and alkaloids probably will not be detected by any of the following simple tests. One which might show heavy metal salts would be the addition of hydrogen sulfide water. An increase in the coloration or precipitates formed, as compared with that formed in a normal sample, would suggest heavy metals. Strychnine would be noticeable by the bitter taste, if present in more than 2 or 3 ppm, an amount well below the lethal concentration. There are general colorimetric tests for the presence of alkaloid groups which probably can be simplified to be applicable to water testing.

Any appreciable quantity of the so-called chemical-warfare agents, agents which might be used in biological warfare or other more commonly known poisons in a water supply will probably produce changes which differ from the *normal reaction* when the following tests are applied to the water:

1. Physical appearance of color, odor and turbidity.
2. pH.
3. Alkalinity.
4. Chlorides.
5. Oxygen consumed.
6. Chlorine demand.

These are simple tests which can easily be performed in the ordinary water-works laboratory by following the procedures outlined in the Standard Methods of the American Public Health Association.

For the above determination to be effective, normal figures for each water supply or each reservoir should be available. Many of the characteristics which are measured by the above tests will vary from season to season, and it is recommended that normal values

on each supply for each particular season should be obtained and kept on record by the water-works laboratory.

Most of the agents which might be added to the water are organic in nature and will tend to affect chlorine-demand and oxygen-consumed values. Insoluble compounds may produce turbidity, while those with odor or color may be noticeable through the physical appearance of the water. Any acidity in the compound used or resulting from hydrolysis may produce changes in alkalinity and in pH.

Unseasonable changes in color, odor or turbidity should all be viewed with suspicion. Changes in the pH value of more than a few tenths may indicate an acid hydrolysis product of a chemical agent. An increase in the pH value might also be significant of the presence of added alkaline compounds. Changes in the alkalinity would undoubtedly be noted, to correspond with any changes in the pH value. Either a decrease or an increase in alkalinity of more than 10 or 15 ppm may have significance.

Some of the "war gases" contain chloride ions and an increase in the chloride content of 10 or more ppm might indicate changes of an unusual nature in the water.

An unusual or unseasonal increase in the oxygen-consumed value, especially if the change is of the order of 5, 10 or more ppm, would suggest the addition of considerable amounts of organic materials to the water. Such a change would be so unusual as to warrant immediate investigation.

Any added organic compounds will undoubtedly affect the chlorine demand of the water in the same manner as the oxygen consumed. Many of the so-called war gases will react with chlorine and produce a noticeable increase in the chlorine demand of the water. An increase in the chlorine demand of more than a few parts per million should call for further investigation.

It should be noted that none of the tests which have so far been suggested are specific in nature. They are only screening tests, which may be used to indicate an abnormal change in the water and which should be used as a warning bell, to indicate the need of immediate and further investigation of the cause of the noted change. They are tests which can be carried on by any water-works laboratory without

too great an effort on the part of the laboratory. The conscientious water-works operator should give consideration to the use of such tests as a means of helping to provide emergency protection for his water supply.

Another suggestion which may have considerable merit is the use of an aquarium. Fish are sensitive to many of the agents which have been discussed. An aquarium could be set up in each laboratory in such a manner that a portion of the water from the supply runs continually through the aquarium, so that fish in the aquarium will be exposed to any chemical or biological agent which might be added to the supply, either as an act of sabotage or as the result of an open act of warfare. The advantage of the use of an aquarium is that the fish are on the job testing 24 hours a day, day in and day out, and it would be necessary only to observe at least twice daily whether they are alive or dead. A test for toxic waste, in which fish are used, is described by F. M. Daugherty, Jr., in the August, 1951, issue of Sewage and Industrial Wastes. In the use of an aquarium the fish would probably be sensitive only to toxic chemical agents and not to biological agents, especially pathogens, such as those of the enteric group of organisms.

One of the most important recent contributions not only to routine water bacteriology but also to emergency water bacteriology is the membrane filter, reported on by Clark, Geldreich, Jeter and Kabler in the July 27, 1951, Public Health Reports. This membrane filter offers the possibility of testing a single portion of water, consisting of several hundred milliliters to perhaps a liter or more of water. In addition, the bacteriological results can be obtained within 18 hours, rather than after several days. One does not need to elaborate upon such advantages to those who are familiar with water bacteriology. Assistant Surgeon General Hollis has stated that the results of these workers promise a substantial reduction in time, labor and space required for specific phases of bacteriological analysis and, at the same time, they indicate a likelihood that these technics will be more certain and precise in results than the methods now in use. With this apparatus, it may be possible, as a routine method, actually to isolate pathogenic organisms from a water sample.

In brief, the equipment consists of a sterile filter for holding the water sample, a source of suction and a biological filter, through which the water is filtered. This biological filter is then placed upon a pad, which has been saturated with an enriching medium to start the growth of organisms on the biological filter. After two hours' incubation, the filter is transferred to a selective medium, to provide for identification of either the organisms of the coliform group or other enteric organisms. Incubation is completed at the end of 18 hours, with the colonies growing directly upon the selective medium. The growth of the colony at this point is similar to that which would be shown on the EMB or Endo plate in the routine completed test.

The technic is as yet still experimental and, unfortunately, there is a lack of availability of the membrane filter. Those used in the work in Cincinnati were prepared by Dr. Goetz in his laboratory at the California Institute of Technology.

Another technic which is to be recommended in the early location of possible sabotage is to establish liaison with your local health officer and acquaint him with the work which you are doing. Ask him to contact you if he encounters an unusual incidence or an increase in illnesses which appear to be water-borne or connected with the water supply. Only liaison of this nature will assist in the early detection of possible sabotage, where the attack has been made within the distribution system itself. For example, the saboteur may wish to strike at a particular area within the distribution system. By renting a house or store somewhere near this point, he might be able to tap the main, inject a chemical or biological agent into the system under pressure, and contaminate a portion of the supply for some time without detection. The first and perhaps the only evidence available of such an attack would be casualties resulting from the attack. The detection of the actual source of contamination then becomes a matter of police work.

A question which immediately comes to mind is what to do in case some abnormality shows in the water supply. Certainly, in such a case, the thing to do is immediately to notify your superior and immediately to acquaint the State Sanitary Engineer with all the facts in the case. Samples of water should immediately be collected

for submission to a laboratory which is equipped to identify the agent which is producing the abnormality.

Where this laboratory will be located and which laboratory it will be will depend entirely upon both local and state Civil Defense organizations. The designating of laboratories capable of identifying chemical-warfare agents and biological-warfare agents is a function of State Civil Defense agencies. Those laboratories can be contacted through your State Sanitary Engineer or through established channels previously arranged in the Civil Defense plan.

In summarizing, I should like to emphasize one of the elements which is very important in connection with the use of weapons of war. That is the element of hysteria. Hysteria may be produced by any specified weapon either among the members of the armed forces of a nation or among its civilian population. Any measure which in any way tends to combat or prevent hysteria is a counter-measure worthy of consideration. This is especially true in Civil Defense work, because hysteria among civilians may be greater than among members of the armed forces. Any measure, however small, which in any way would tend to lessen or eliminate hysteria decreases to that extent the effectiveness of the enemy's weapon. With the possibilities of concurrent hysteria removed, a weapon may become so ineffective as no longer to warrant its use.

This leads up to a discussion of the effectiveness of the simple measures which have been suggested. We have considered very briefly a wide variety of poisons and materials which might be added to a water supply deliberately or as a result of some open act of warfare. Even with the most poisonous of these, large amounts of the chemical would be required to contaminate a reservoir completely. Where the toxicity of the chemical is of the order of a milligram of the chemical per kilogram of body weight, approximately 500 lb of the chemical would be required to contaminate a million gallons of water. For a large city, the contamination of even a day's supply of drinking water would represent several times 500 lb and to contaminate completely a large reservoir many times the 500 lb. Even with the more poisonous materials, the chances of complete contamination of a reservoir seem somewhat remote. If we superimpose upon what appears to be

a rather impractical attempt to produce casualties and hysteria any laboratory procedures, however simple, which might detect the contamination and so prevent the anticipated results, then we have made that attempt even less effective and so lessened the possibility of its use.

What has been suggested is not the solution to the problem of detecting contamination in drinking water or of preventing the contamination of drinking water. It is only a series of simple procedures which may help in early detection of contamination resulting from sabotage or from acts of open warfare. The results obtained are only sign-posts to help guide one's way onto the highways which lead to more positive information. These tests are simple to perform; they are quick to perform; the results are obtained immediately, and may be the first indication that something abnormal has taken place in the water. Abnormalities can be noted only by comparing the results of these tests with normal values for each test and evaluating possible causes of changes from the normal values. It is the change from the normal figure which cannot be explained by wind, rain, snow, or other known circumstances, rather than the absolute figure, which is significant. The answers obtained from this suggested program will never be black or white but will always be in the indefinite grey zone, but even so, they may be of considerable significance.

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SANITARY SUPERVISION OF MAINE WATER SUPPLIES

BY HOWARD H. POTTER*

[*Read November 15, 1951.*]

The Maine public utility law defines a water company as any person or corporation owning, controlling, operating, or managing any water works for compensation. The definition of a water works is sufficiently broad to include even the individual with a spring on the hillside back of his house, who, having piped it down to his house, then out of the kindness of his heart is willing to sell some to his neighbor. The definition then continues to state that water companies are public utilities.

Thus all water supplies, whatever the size, whether privately or publicly owned, are public utilities and subject to the jurisdiction of the Public Utilities Commission. The Commission fixes the rates which the utility may charge and is, therefore, the only state agency in a position to authorize expenditures for plant additions.

Furthermore, when the public utility law was passed and the Commission created in 1915, there was no health department such as we know it today. Instead, there was a Board of Hygiene, if my memory serves me correctly, employing one chemist, with sometimes one or two assistants during the summer, who tested water samples on request. The Commission, considering water quality to be an element of service, frequently called upon this chemist to test samples which might be suspected, but for a long period there was no regular system of sampling. And as there were no sanitary engineers, inasmuch as there was no health department, the Commission engineers had to assume the responsibility.

However, as time passed, the Board of Hygiene eventually became the Bureau of Health; the water laboratory expanded, and the Division of Sanitary Engineering came into being. The Division at this time still remained under the direction of a chemist, and the Director and a Commission engineer frequently traveled together in checking

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and supervising water supplies. Then the chemist resigned to accept private employment and, when Dr. Campbell, the present State Sanitary Engineer, took over in 1923, the Division consisted of himself and one stenographer. Today there are ten full-time chemists with an additional four taken on during the summer months. Approximately 60% of the work of the laboratory is water analysis. The Division also has seven full-time sanitary engineers.

In times of epidemic or other comparable emergency the Bureau of Health with its staff of sanitary engineers would assume complete control. Under normal conditions the sanitary supervision of water supplies is exercised by the Public Utilities Commission, which has complete authority to issue orders on all matters relating to service, including needed treatment facilities. The Commission also issues the order to a utility to notify its customers to boil all water used for domestic purposes, when such an order becomes necessary. The Bureau of Health has no authority except to act in an advisory capacity. Such advice may be sought by the public, by the utilities or by the Commission, but in the first instance requests from the public are usually referred by the Bureau to the Commission. Water analyses, as already stated, are made by the Bureau's laboratory, but the sampling schedule was instituted by the Commission, with the advice and consent of the laboratory, and the enforcement of the schedule rests with the Commission through its General Order No. 2480, issued in 1920.

Summarized, this order states that whereas all public water supplies are utilities, and whereas the Commission may summarily, with or without notice, investigate the service rendered by any utility, and whereas the service of any water company includes the quality of the water, and whereas the quality can only be determined by careful analysis, it is therefore ordered that all water companies furnish the laboratory, in receptacles supplied by that department, quantities of water for analysis whenever requested by the Director of the Division of Sanitary Engineering. While the order does not specifically say so, the receipt of a bottle constitutes a request, and failure to send in a sample is a violation of a Commission order, placing the utility in contempt of the Commission, which is punish-

able to the same extent and in the same manner as contempt is punished by courts of record.

Under the sampling schedule properly protected ground-water supplies submit samples quarterly in January, April, July and October. All other supplies, except those which render summer service only, submit samples monthly. Summer supplies, having surface mains, send in samples during the months of June, July, August and September. Most of the utilities submitting monthly samples own their own shipping cases, containing four bacteriological bottles, which are used ten months of the year, but all supplies, except the summer ones, are required to submit gallon samples for complete chemical examination in the months of April and October, and of the four samples submitted by the summer supplies the first one in June is a gallon sample. Should any one of the regular samples be unsatisfactory, check samples are required for as long as the unsatisfactory condition persists.

The total number of utilities is divided into approximately four equal parts and containers are sent to the first fourth on the first Friday of the month, to the second fourth on the second Friday, and so on. Samples are expected to be back in the laboratory on the second Friday after the containers are sent out. As already stated, the responsibility for maintaining this schedule rests with the Commission.

There are 161 water utilities in the state. Of these 18 are municipal departments, 42 are quasi-municipal water districts, the remaining 102 being privately owned companies. They range in size from Portland with 40,734 service connections down to one in Columbia Falls with only 5. Thirty-three utilities have over 1,000 service connections and 40 have less than 100. The total number of service connections for all utilities is 182,591. With the usual 3.5 persons per family it is not unreasonable to assume that approximately 639,000 persons are served by public water supplies. The 1950 census gave Maine a population of just under 914,000, which means that 70% of the population is so served.

At this point it might be well to interject a few statistics as to the nature of the Maine supplies and types of treatment, as of the present time:

Description	No. of utilities	%	No. of serv. conn.	%
Surface Water	98	61	157,809	86
Ground Water	60	37	20,213	11
Combination	3	2	4,569	3
Chlorination	104	65	170,734	94
Simple Filtration	10	6	11,620	6
Complete Chemical	10	6	30,093	16
Surface—No Treatment	11	7	3,274	2
Ground—Some Treatment	17	11	16,199	9

From Kittery in the south to Fort Kent in the north is about 450 miles, and from the New Hampshire line in the west to Eastport is about 300 miles. With 161 utilities and distances being what they are, it should be rather obvious that for one man to give every utility an equal amount of attention would be well-nigh impossible. My efforts, therefore, have to be concentrated on those places which the records show are most in need of it. The places that we know are all right may see me only when it is possible for me to stop in passing through to pay a brief courtesy call. The District Engineers of the Health Department are able to be of assistance, and do help immeasurably, by dropping in from time to time on the utilities in their districts and either giving helpful advice or reporting to me anything they think should have my attention.

Early in my work with the Commission it became very apparent, as just stated, that the major part of my effort would have to be directed toward the places most in need of it. To determine what places was the question. It was obvious to me, as it would be to anyone in a similar situation, that if a system of numerical rating could be devised the question would be answered. A little research disclosed that in 1927 this Association had adopted as a tentative working system a method of scoring recommended by a committee consisting of Arthur D. Weston, only recently chief engineer of the Massachusetts Department of Public Health, J. F. Jackson, formerly chief engineer of the Connecticut Department of Health, and E. Sherman Chase, of the firm of Metcalf & Eddy. Later, in 1931, at a meeting of the American Public Health Association a committee was appointed to

work with similar committees of the State Conference of Sanitary Engineers and the American Water Works Association, to study the feasibility of working out a scoring system covering the sanitary quality of water supplies which might be used nation-wide with a reasonable degree of accuracy. Mr. Chase discussed the work of this committee in a paper before the AWWA in 1932. Hence it is not without a feeling of considerable temerity that I proceed from this point.

Mr. Chase began his paper with these words: "The alchemist sought the philosopher's stone whereby to turn lead into gold. The Spanish soldier of fortune explored the New World for the fountain of perpetual youth. So, today, does the sanitary engineer seek a single standard by which to judge the quality of water supplies. Perhaps the modern quest is as little likely of success as those endeavors of the past."

It is not my intention to review at this time the scoring system suggested by Mr. Chase. For those of you not already familiar with it and who are sufficiently interested, it may be found in Vol. 24 of the Journal of the AWWA. Suffice it to say that if my department had available the number of sanitary engineers necessary to collect the basic information from 161 utilities, the rating schedule would not be needed, at least not for the reasons which have already been given above. And let me assure you, that is not meant in any derogatory sense, for I still believe numerical scoring to be desirable, and the more complete it is the better.

Therefore, disregarding pollution hazards and protective measures, we come to quality conditions. Even here I did not attempt to consider each item such as turbidity, color, odor, taste, etc. Not that these are not each and every one important, but, as you have already seen, the utilities equipped to remedy these conditions, if they existed, are relatively few and the remaining ones financially able to provide the means are even fewer. More than that, by and large, Maine water supplies are not too greatly bothered by these disadvantages. Those of you who are familiar with Maine can doubtless name one or two, but out of 161 supplies they are relatively insignificant.

The items that seemed important to me were *B. coli* and high salt content, indicative of pollution. And to these must be added one other factor—namely, the promptness with which samples are submitted. We have only three utilities in the state with their own laboratories, and one sample per month, or four samples per month, all submitted at the same time, are none too many. On a population basis it is not enough in some cases. Especially in the case of check samples it is of the utmost importance that they be returned promptly. One week is allowed.

My scoring ranges from 1.0 to 5.0, 1.0 being satisfactory. Thus, for a satisfactory report from the laboratory submitted on time, the scoring is 1.0. If coliform bacteria are confirmed in two or three out of five 10-ml samples, the scoring is 2.0. If coliform bacteria are confirmed in four or five such samples, the scoring is 3.0. Also, if there are positive evidences of chemical pollution, the scoring is 3.0. If both confirmed *B. coli* and chemical pollution, the score would be the sum of the two, not to exceed 5.0. And in such rare instances as may be necessary to issue an order to boil the water before using, the scoring is 5.0.

As indicated earlier, in the case of regularly scheduled samples the utility is allowed two weeks from the time the container is shipped before the sample is due back in the laboratory. For each day over two weeks there is a scoring penalty of 0.05. One week from the time of an unsatisfactory report is allowed before the check sample becomes overdue. And again for every day it is late there is a penalty of 0.05. However, as a reward for promptness there is a deduction of 0.02 for every day under a week.

Every laboratory report is entered on the scoring sheet as it is received. At the end of the month the scores are averaged to arrive at the monthly rating, and the monthly ratings are averaged for each twelve months to give the annual rating. Thus, when the utility has an annual rating of 1.0, it means that it has not had one unsatisfactory sample nor one late sample in a year's time. As of the current month, there are 79 utilities, or 49% of the total, that have such a perfect rating. If we add to these 40 more utilities with an annual rating of 1.10 or less, which represents not more than two or three poor samples out of 40, we have 74% of the total.

At the end of the month both the monthly ratings and the 12-month ratings are averaged by companies. That is, the average by companies is the sum of the 161 monthly or twelve-month ratings, as the case may be, divided by 161. The weighted average by service connections is obtained by multiplying each monthly or 12-month average by the number of services and dividing the total by the total number of service connections. On the face of it this may seem like a lot of work, but actually the month's computations can be made by a girl with a calculating machine in about two hours' time.

This scoring system was started in 1932 after discussing it at considerable length with Dr. Campbell of the Division of Sanitary Engineering. For two years it was on an experimental basis and in that time several changes were made in the original system. Since 1934 there has been no change, and a graph has been kept which plainly shows a gradual but steady improvement in the quality of the water being turned out.

For example, in the summer of 1934 the monthly rating on a company basis went as high as 1.71 and the monthly rating by services was 1.41. The 12-month rating by companies toward the end of that year reached 1.56, the highest it ever went, and the 12-month average by services went to 1.25.

Of course the monthly ratings rise and fall with the seasons, the highest being in August or September. The highest reached this year on a company basis was 1.17 in August, as against the 1.71 in 1934. The highest this year on a service basis was 1.05 in July, as against 1.41 in 1934. The twelve-month rating by companies as of the present month is 1.12, which compares with 1.56 in 1934, and on the basis of service connections is 1.02, in comparison with 1.25 in 1934.

There is, of course, not the slightest doubt in my mind that plenty of fault can be found with this scoring system. The one which probably comes first to mind is that it gives no consideration at all to what might be called the esthetic qualities of the water, such as taste, odor and appearance. This objection is readily granted. But please bear in mind that my objective was primarily to picture first numerically and then graphically the safety of water supplies, so that my attention could be focused on those places most in need of it.

Mr. Chase, stating the reasons why a scoring system was desirable, said: "Judiciously used, comparative scores may be employed to stimulate competition in water supply betterments between rival municipalities." The Maine Commission had much the same idea, as a result of which it publishes every year in its Biennial Report to the Legislature the current ratings for each utility. This report is, of course, public and can be obtained from the Commission on request. It has, as a result, a rather wide circulation. While I have no means of knowing to just what extent it stimulates competition, there is no doubt it plays a part.

Improved equipment and improved technique and greater knowledge on the part of the operators have undoubtedly played a great part in the steady downward trend of the curves. It would be presumptuous in the extreme for me to claim all the credit for the improvement noted above. But that the scoring system has served a purpose, at least in part, is borne out by the rise of all four curves during the years 1943 and 1944. At that period I was on leave of absence from the Commission, to serve as Regional Sanitary Engineer of the First Civilian Defense Region. During that time only as much of my work as was more or less of an emergency nature was done by one of the other Commission engineers. The rest had to be held in abeyance until my return.

There are a certain few of the smaller utilities having groundwater supplies which show evidences of chemical pollution. Because of lack of sufficient revenues there is little or nothing that can be done to correct these conditions. And it is probable that, no matter how great the vigilance, there will always be an occasional bacteriological analysis that will not be all it should be. Certainly the millenium would be reached if ever a month went by without at least one late sample.

For these reasons it is impossible to look forward to the time when all monthly and annual ratings will be 1.0. As the annual ratings have held almost steady for the past two or three years, it is, therefore, probable that the time has already been reached when no further drastic improvements can be expected. Still there will always be plenty to do to keep the ratings where they are.

Somewhat as an afterthought it might be added that some 35 of the larger utilities are submitting monthly operating records showing for each day of the month the temperature, weather, name of the operator, the hours of pumping and amount of water pumped, the amount of chlorine used and the chlorine residual.

For several years before the war it had been my constant suggestion to operators that such a record be kept, not always, I am sorry to say, with too much success. While I was on leave of absence during the war, Mr. J. E. Hale, the Acting Director of the Division of Sanitary Engineering and State Water Coördinator, convinced the Commission of the desirability of having such records from some twenty-odd utilities directly connected with the war effort, and the Commission issued an order requiring it. After the critical period passed, the Commission was loath to continue the order in force, but most of those utilities are continuing the reports voluntarily and almost an equal number of utilities has since agreed to adopt it. It should not be necessary for me to elaborate on the innumerable instances when such reports have proved useful. Combined with the numerical scoring system, these reports give me a general picture of any particular utility during any given month.

EXPERIENCES IN OPERATION OF A SMALL WATER DEPARTMENT

BY FRED E. COLBY*

[*Read November 15, 1951.*]

The town of Bridgewater, Mass., has an area of 28 1/6 sq. miles with a population of 7,500. It has 74 miles of roads and about 1,590 houses. The State Teachers' College is located here, as well as some manufacturing plants, such as 2 leather-board mills, 2 shoe factories, 2 foundries, 1 nail manufacturing plant, a laundry and a grain elevator. The outlying districts support market gardens, poultry farms and dairy farms.

The water supply is derived from 2 gravel-packed wells, one of which is 68 ft deep and is operated automatically by electric power at 800 gpm. The other is 57 ft deep and is manually operated and powered by Diesel at 500 gpm. There are 2 standpipes, with capacities of 275,000 and 990,000 gal, respectively. These gravel-packed wells are in the center of an arc of pipe-line, with standpipes on either side. They are located on the extreme easterly side of town.

The first pipes, laid in 1883, were mostly 4-inch and 6-inch. In 1912 the pumping station, which was of the steam type, was moved from the foot of Sprague's Hill to a location beside the Matfield River, near the East Bridgewater town line, and 67 tubular wells were driven for water at this site. These proved inadequate due to sand and rust. In 1925 Bridgewater had a serious fire, which destroyed a business block in the center and the State Normal School. The town then purchased the water company which up to this time had been a private enterprise. New pipes were laid on the oposite sides of the streets from the old lines. Gradually these old lines were discontinued. There was little activity in the water department until 1936, when pipe was installed on a few streets.

In 1946 the town started to expand and an engineer was hired to make a survey. He recommended the various extensions, the tying-

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in of dead ends and the laying of new mains on the back-country roads, to reinforce the present system, as well as another standpipe on the west side of town to provide adequate flow of water for fire protection. He also recommended a new gravel-packed well, to be the first project of a ten-year program.

At the following town meeting in March the voters were demanding water mains on various streets and voted in 5 miles of mains and 1 gravel-packed well. The following year they upset the original plan by voting 15 miles of mains on streets designated at the town meeting. Since then, each year more mains have been voted in, with the result that now we have some 59 miles of mains and 2 gravel-packed wells. There are 1,650 services and 310 hydrants.

Before the spending spree started, we were doing general maintenance work, such as putting gates on old hydrants. Due to new construction, this work slipped behind and piled up.

Added to our work were 9 hydrants, broken off by cars. We charged for the broken hydrant and for the labor of removal and setting of a new hydrant, as well as for the estimated amount of water lost. Usually the person damaging the hydrant turns the matter over to his insurance company for settlement. The insurance companies also want us to salvage the good parts of a hydrant and pay only for the broken part and the labor to replace it. The lost water always causes argument, but so far they have always paid. My argument is that our resident customers have to pay a water bill if it runs over, due to faulty fixtures, so why should an insurance company be exempt?

Now as for troubles—we had a break in a water main and could not shut down completely, due to a faulty 10-inch valve. We repaired this leak with the line loaded and really got wet. Later that night we shut down two other valves on each side of the faulty one, in order to take it apart. We found a piece of 2 × 4 about 4 ft long and removed it by sawing it in short pieces, a very slow operation. Another time we got two caulking irons and a hammer out of a line against a valve-face. The hammer with a new handle is now in use—we figured it had been in the line since 1925.

We have unusually good coöperation with our neighboring

towns. We are connected with East Bridgewater on the east side of town and West Bridgewater on the north side. There are 2 valves at each town line which are normally closed, but which in an emergency are opened. A short time ago West Bridgewater had a serious fire; the valves were then opened. In East Bridgewater their main feed-line is on the east side of town while our main feeder is on their west side. When their main feeder-line needed repair we opened up our valves to supply them. The superintendent of each town is supposed to open or close his own valve but we have an agreement whereby in an emergency any one of the three can open them, notifying the other at the first opportunity. We also supply each other with trucks, men and material in time of trouble. There has been no charge to date for this service. At one time the commissioners were not in accord with this plan, but the three superintendents continued to coöperate.

We have very little labor trouble. The men are on salary. We try to work a 44-hr week, with vacation and sick-leave allowed. There is now good coöperation between town departments. In the past, the Water Department has patched its own road holes, but now the Highway Department takes care of them. In all cases we try to make the opening as small as possible and nearly always drive or wash a service under a street. Once a week I give a list of the completed jobs to the Highway Superintendent. We coöperate with the Fire Department in that a truck and men report to all fires. These men are paid yearly by the Fire Department for this service in addition to their regular salary. In the winter, if not too busy, the men help the Fire Department shovel out the hydrants. In return, the Fire Department tests new lines with its pumping equipment.

The services in town are 99% metered to date. Previously this was not so and the revenue was small. It has been my practice with complaints to listen carefully and not be too quick to give a decision. A little patience and explanation usually make a contented customer. Sometimes they do not realize that they are a part of the organization and little do they realize where their water comes from. I invite them to the plant and show them the various steps before they get

their water from the tap. Most of them go away boosting the Water Department.

While all departments have their headaches and gripes, there is the amusing side, too. We had an emergency call to a lady's house. Upon arrival we found that she wanted the legs sawed off of an iron bed. She called us "because we had iron-saws and worked on iron pipe" was her explanation. We obliged. One woman complained on a minimum water bill. She said that she and her husband hadn't drunk any water for a month. They only used beer and wine and furthermore used the little house at the end of the path. I explained that there was a minimum charge, regardless.

It has been my experience that water departments do not advertise to their own townspeople. They do their work, absorb all the complaints and apologize when they ask for improvements in the department. This should not be the case; the water is perhaps the most important utility. The last few years I have tried to educate the people in this matter and, if you show them what they own, how it works and how it can be improved upon, you usually have their loyal support when it is needed.

DESIGN AND OPERATION OF AN AUTOMATIC FILTER IN WINOOSKI, VERMONT

BY WILFRED C. GILBERT*

[*Read November 15, 1951.*]

The city of Winooski, Vt., with a population of 6,700, is situated just north of and adjacent to Burlington, across the Winooski River. Like Manchester, N. H., and Woonsocket, R. I., its people are predominantly of French-Canadian origin. The principal industry is a large unit of the American Woolen Co.

The water supply is municipally owned and is operated by the city Water Department, of which Leo Contois is superintendent. Briefly, the water is collected in three impounding reservoirs, chlorinated at the upper end of the lowermost reservoir, filtered at a treatment plant below the lowest reservoir, and pumped into the distribution system, with a 500,000-gallon standpipe riding on the system, to provide pressure and storage when the pumps are shut down. The filter is contained in a two-story building, 50 ft by 47 ft, which also houses the pumps and provides storage space for the chemicals used in the treatment processes (see Fig. 1). The building is constructed half-above, half-below ground level, so that as one enters, he is walking on the roof of one of the treatment basins and the pump room is one floor down. The heart of the plant is the automatic filter itself, which extends across the entire southern wall of the building. I should like to work upstream from the filter to the source of the water, then downstream to the main going to the city, and then in this setting describe the filter.

The water comes to the filter from a coagulating basin, which measures 14 ft across and 28 ft long and has a water depth of about 9 ft 8 in (see Fig. 2). At the usual operating rate this provides a detention period of 32 minutes. There is no sedimentation following flocculation and the floc all goes onto the filter. The basin is equipped with two Foote Brothers type HGV flocculators, each driven by a

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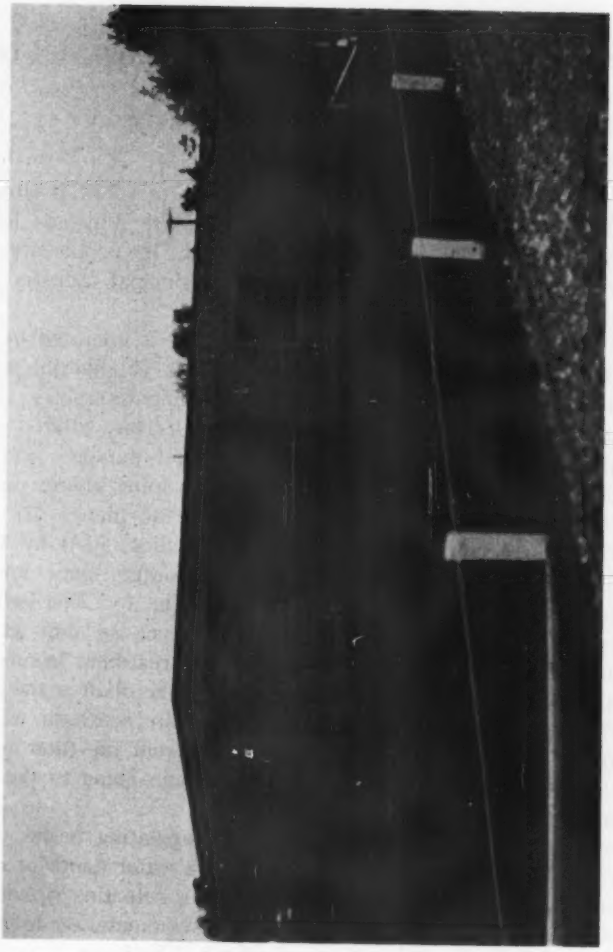

FIG. 1.—EXTERIOR VIEW OF WINOOSKI FILTRATION PLANT.

1/2-hp electric motor. At the head end of the basin, chemicals are fed into the water by two Wallace and Tiernan dry chemical feeders, type MOF, one used for alum and the other for activated carbon, chlorine powder, or usually just as a standby for use in feeding the alum. These chemicals are flash-mixed by a Mixco model 1AWQ mixer in a mixing chamber 3 ft square and 5 ft deep. Ahead of the mixing chamber there is a Ross regulating valve, which shuts off the flow of water to the filtration plant when the pumps shut down. A 10-in. line brings water by gravity to the plant from the sources, which include 3 reservoirs and 5 deep wells, with a total watershed of less than one square mile. The soil on the watershed consists mostly of silt, and as the vegetative cover is sparse, the silt is washed into the water supply with every heavy rain. This is the factor which gave rise to the demand for a filtration plant.

The effluent from the filter flows over a weir about midway of the interior side-wall of the filter and passes down *under* the filter. A clear well extends the length and width of the filter and, with a water depth of 5 ft 6 in., this basin has a capacity of 32,000 gal. I should like to point out that from the reservoirs through to the clear well the water flows entirely by gravity. From the clear well the water is pumped into a 10-in. main going to the city. There are duplicate pumps for this purpose, each being a Fairbanks Morse centrifugal pump, capable of delivering 700 gpm against a head of 193 ft. One pump is driven by a 50-hp Fairbanks Morse Line-Start electric motor and on the same drive-shaft, on the opposite side of the pump, by a 6-cylinder Continental gasoline motor, which is maintained as a standby. The second pump has an electric motor similar to that on the first pump.

Because the Winooski supply has been deficient in quantity in recent dry years, the wash water from the filter is not run to waste, but rather flows into a sump measuring 8 ft square by 10 ft deep, whence it is pumped back onto the watershed.

The Filter

The filter itself is pictured most easily perhaps as a series of very narrow conventional filter units, laid side by side like the slices in a loaf of bread (see Fig. 3). Each unit receives coagulated water

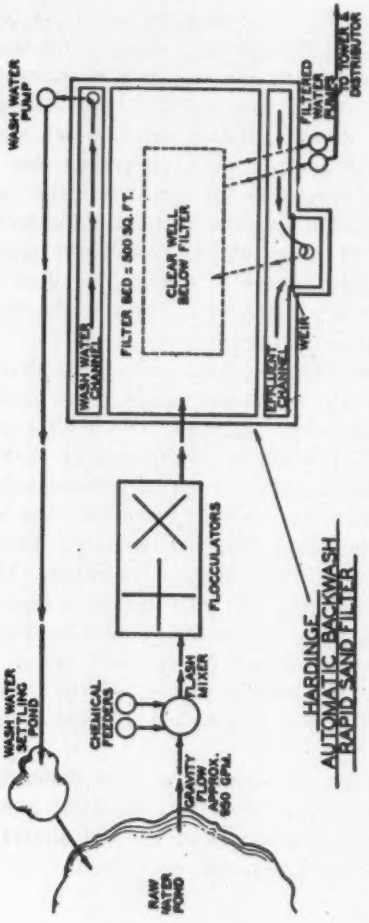

FIG. 2.—FLOW DIAGRAM OF WINOOSKI FILTRATION PLANT.

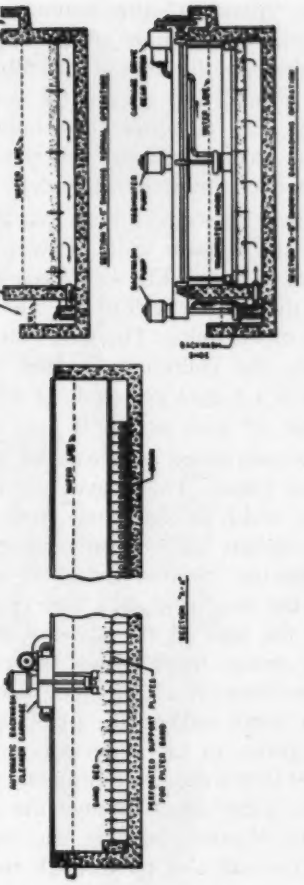

FIG. 3.—MECHANICAL DRAWING OF HARDINGE AUTOMATIC BACK-WASH FILTER.

through a porthole on one side. The water floods across the filter unit, which is 12 1/2 ft wide. It filters downward through 11 in. of filter sand, through an "Alundum" filter bottom, and into a 6-in.-deep chamber under the carborundum filter plate. From here it flows out another porthole on the opposite side of the filter from the influent port and up through a small hole cut in the wooden bottom of an effluent channel, which runs alongside the length of the filter. The effluent flows into this channel, joining the effluent from the other filter units, and passes over the weir to the clear well.

There are 60 of these filter units. Each unit is 8 in. across, which, with the thickness of the division walls between added in, makes a total filter-bed length of 43 ft (see Fig. 4). Water from the coagulating basin flows around to the exterior wall of the filter and simultaneously enters the ports of 59 of the units. The filter effluents are also simultaneously flowing into the collecting channel from the 59 units. The rate of filtration is 1.8 gpm per sq ft of filter surface and the backwash rate is about 12 gpm per sq ft.

Backwashing is accomplished by means of a traveling carriage, similar to an overhead crane. This moves the length of the filter, thus going *across* the width of each unit, rolling on railroad-type rails mounted on the concrete walls on each side of the filter bed (see Fig. 5). A bonnet like an inverted trough is suspended from the carriage and extends the length of each filter unit, just grazing the top of the sand and the tops of the division walls between units. A 100-gpm Economy pump, mounted on the carriage, pulls dirty water from the bonnet through a 2-in. pipe and discharges it into a metal gutter on the south wall of the plant, and the wash water then flows from the gutter to the sump for pumping back to the watershed. At the same time a duplicate Economy pump, also mounted on the carriage, forces water down through the hole in the wooden bottom of the effluent channel, pushing the water into the 6-in. chamber under the filter unit and up through the filter bottom and filter sand.

When a predetermined loss-of-head is reached through the filter, the electric motor moving the carriage is activated and the carriage progresses the length of the filter, at a rate of 42 in. per minute, until

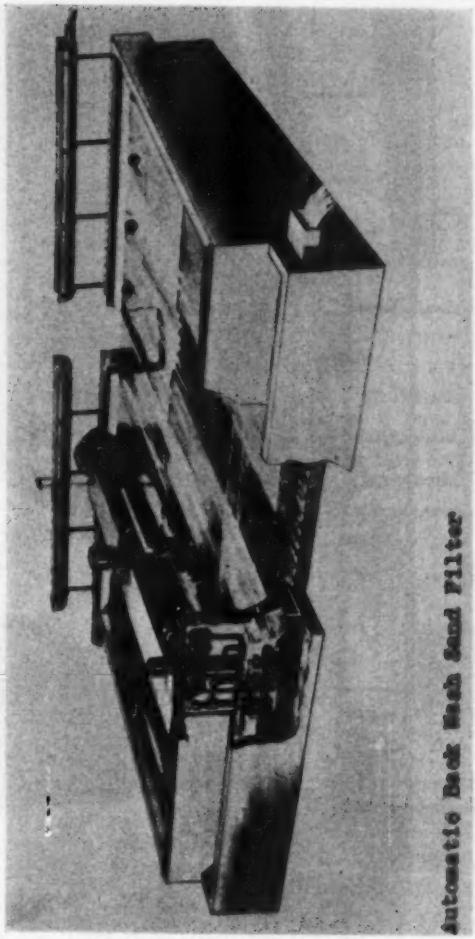

FIG. 4.—ARTIST'S CUT-AWAY DRAWING OF AUTOMATIC BACKWASH FILTER.

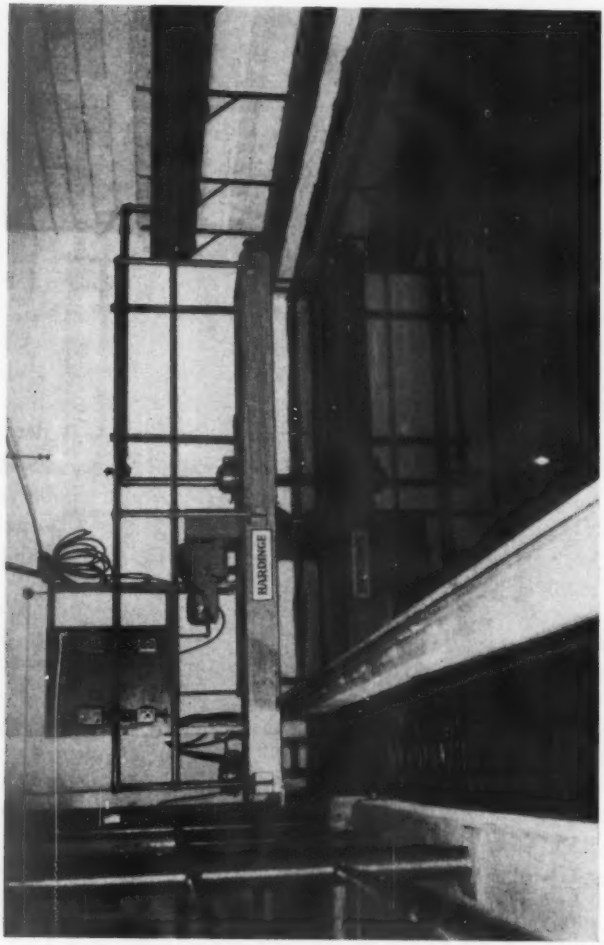

FIG. 5.—PHOTOGRAPH OF FILTRATION BASIN, WINOOSKI FILTRATION PLANT, SHOWING BACKWASH CARRIAGE.
(Photo by E. L. Tracy, Vermont Health Dept.)

enough filter units have been cleaned to reduce the loss-of-head to another set value. It then stops until the loss-of-head has built up again.

The pumps which force water from the clear well to the distribution system are controlled by pressure switches. These are set to shut the pumps down when the standpipe across the city is full. When these pumps stop, the backwashing mechanism does not stop, but continues to operate until the loss-of-head has been reduced as described above.

Men Who Figured in Design and Construction of Plant

The construction of the plant was begun May 31, 1949, and it was first put into operation on July 27, 1950. The design is patented by the Hardinge Co. and the Winooski plant represents the second application of their automatic backwashing filter scheme to a public water supply, it being used previously for industrial waste-disposal work and for the village of Newton Falls, N. Y. Mr. W. C. Laughlin of that company collaborated with Mr. Fred Gibbs, of the Engineering Sales Corp. and a member of this Association, in the design and installation of the filter. The building itself was designed by Mr. Arthur Hoag, civil engineer of Burlington, Vt., and built by Mr. Walter Adams, a Burlington contractor. The plant was set in operation under the guidance of Mr. Hugo Bergman, engineer of the Engineering Sales Corp. and also a member of our Association. He has visited the plant a good many times since and has been of great help to the plant operators.

Cost

I should like to present some information about the cost of the plant. The entire cost was $70,440, including $14,500 for the Hardinge filter, $30,000 for the general contract, $3,000 to the engineer designing the building, $2,500 for the electrical contract, $5,540 for the chemical feeders and mixers, and $4,880 for the pumps and motors, exclusive of those mounted on the backwash carriage. The cost of operating the plant runs about $12,000 a year, with $4,930 for the retirement of the bond issue for the plant, $2,600 salary for the plant operator, $2,400 for electricity, $500 for fuel oil for heating the

building, $950 for aluminum sulphate and $360 for chlorine. At a yearly plant output of 113 mil gal, the cost per million gallons of water figures out at $106.

Our Appraisal

There would appear to us to be two disadvantages. One is the high unit cost of treating the water. The price of $106 per million gallons can be partially explained by the fact that the plant is overdesigned, to take care of additional water which is needed now and has not yet been found. All of the filtration and pumping is now done in a 7-hour day and, of course, if these steps were carried out continuously, 3 1/2 times as much water could be treated.

Another drawback is the general contrariness of anything mechanical. You can imagine that the controls for the automatic operation of the plant must be painstakingly adjusted and set within close limits. The first time Mr. Bergman came back to Winooski after setting the plant going, he found that the local people had done considerable re-wiring and re-adjusting, and I guess he thought for a while he was in the wrong church. The present operator, Mr. E. Harmon Kelly, understands the interrelationships of the various units and their controls (he was formerly employed in technical work) and maintains the works in proper order. A good replacement for Mr. Kelly might be hard to find at $50 a week.

To illustrate what we mean—on one occasion the Ross regulating valve failed to function properly, because of a faulty adjustment of its controls. The result was that when the pumps stopped sending water from the plant to the city, the water coming into the plant did *not* stop also, but continued to run until the filter overflowed and the pump room was submerged in several feet of water. That was on a weekend and, since the plant was operating automatically, no one was in attendance and the overflowing continued for some 18 or 20 hours.

The only advantage to the use of the filter is the improvement in the physical quality of the water. There is no increased safety from a sanitary standpoint, because the unfiltered water already is bacteriologically satisfactory, with a strong chlorine dose applied.

In fact, on several occasions the wash water has shown an absence of coliform bacteria.

Last December 5 and 6, following torrential rains, the filtration plant was deluged with muddy water. A beakerful of this fluid, when settled for a few hours, would show the bottom 20 or 25% of depth full of silt. Unfortunately our State Health Laboratory does not measure sediment and turbidity according to Standard Methods, but uses a number scale running from 0 to 5. However, as a guess we estimated that the raw water had a turbidity of 500 ppm. This was reduced by filtration to about 200 ppm. Except during times of heavy run-off, the filter does remove substantially *all* of the sediment, turbidity and color. Following is a typical analysis:

Date of collection: November 1, 1951	Influent	Effluent
Sediment	1	0
Turbidity	1	0
Color—ppm	20	5
Odor	0	0
pH	7.35	7.2
Hardness—ppm	100	102
Chlorides—ppm	25.5	25.4
Albuminoid Nitrogen—ppm	0.072	0.048
Ammonia Nitrogen—ppm	0.012	0.012
Nitrite Nitrogen—ppm	0.000	0.000
Nitrate Nitrogen—ppm	0.83	0.88
Copper—ppm	0	0
Lead—ppm	0.08	0.01
Iron—ppm	0.2	0.0
Calcium—ppm	54	52
Magnesium—ppm	46	50
Total Alkalinity—ppm	72	68
Carbon Dioxide—ppm	5.4	7.0

Closing

The Water Department in Winooski would welcome any visitors from this Association, if you should be passing through. My thanks are extended to Mr. Garrow and Mr. Kelly, of that Department, for their help in writing this paper, and to the Hardinge Co. for the use of their slides.

SANITARY CONTROL OF SURFACE-WATER SUPPLIES

BY WILLIAM A. HEALY*

[*Read at Chemists' Round Table, Dec. 20, 1951.*]

When I was first asked to prepare some material for the Chemists' Session, it was suggested that it should include a discussion of bacteriological problems relating to all types of water supply, including ground waters, rivers and lakes. To attempt to do this in the short time that is available did not seem practical. Therefore, I shall confine the discussion to quality considerations relative to surface-water supplies, especially those of lake or pond nature.

As perhaps some of you may know, we in New Hampshire are at the moment especially concerned with this phase of water-supply sanitation. In the first instance, there is an appeal now pending to the Supreme Court, wherein the State Board of Health has requested that the court review a Superior Court decision, which declared invalid certain regulations, promulgated by the Board for the protection of the water supply of the City of Manchester, which incidentally is taken from Lake Massabesic. The regulations in question provided that no human activity of a recreational or other character could be conducted in the West or so-called Back Pond intake area of Lake Massabesic.

Secondly, this past summer, we experienced a pollution problem in connection with the Concord water supply, which clearly demonstrates the need for maintaining adequate safeguards in the way of controlling and restricting activity in and about surface sources of water supply which are treated by chlorination only. Unfortunately, there seems to be increasingly a tendency to lose sight of or to minimize some of the sanitation practices fundamental to the production of good raw-water quality. Undoubtedly this situation arises, in part at least, because of the great reduction in the numbers of water-borne epidemics of typhoid and paratyphoid fever which has resulted

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over the last several years, because of the application of sound water-works practices. While the record with regard to typhoid is good, as will be mentioned later, there are other water-borne intestinal illnesses that can be and are regularly contracted because of failure adequately to maintain proper sanitary safeguards for the protection of raw-water quality. Again I have particular reference to those sources where the only form of treatment is chlorination. The Concord problem, which I shall describe briefly, serves as an excellent illustration of the danger that can be expected whenever a serious breakdown develops in the protective aspects of water-supply control.

As a background to the Concord situation, I should mention that the Concord main source of supply consists of Penacook Lake, which is located approximately three miles northwest of the city proper and is at an elevation about 125 ft higher than the central section of the city. The lake is approximately 2 1/2 miles long, averages 1/4 mile in width and has a surface area of 359 acres. The storage capacity of the lake above the intake level amounts to 1,500 mil gal. The watershed area tributary to the lake is in the vicinity of three square miles and the safe dry-weather yield has been estimated at 2.7 mgd. The drainage area, for the most part, is only sparsely inhabited, with the greater proportion of the shore-line area controlled by the Water Department.

Service to the city is by means of two mains, one a 20-in. cast-iron line and the other an 18-in. cement pipe. About 40% of the water used in Concord is supplied by gravity and the remaining 60% pumped. The two mains are joined at the pumping station, located at the junction of Boutin and No. State Streets. At this station water is pumped to the high-pressure reservoir, having a capacity of 2.5 mil gal, which is located off Penacook St., about 3/4 mile west of the pumping station. It is an earth-embankment structure, open at the top and lined with granite blocks. There is also an extra high-service system, serving the hill areas, which takes suction from the supply line to the high-service reservoir. This unit consists of a booster pumping station and a 250,000-gal steel standpipe. In addition to the foregoing, the Water Department recently completed the construction of a pumping station to serve the Penacook section

of Concord. Formerly, water was distributed to Penacook by means of a 14-in. branch from the high-service system in the city proper. Both pressure and quantity of supply under this arrangement were unsatisfactory; hence the new pumping station, supplying the area independently from the rest of the system, was required and placed in operation in 1950. This new station is located near the gate house at Penacook Lake. Although not involved in the pollution problem, as it occurred late this summer, the water-works system also includes a driven-well field, consisting of 150 2 1/2-in. wells, averaging in depth about 40 ft. The well field is located in the Soucook River valley, approximately three miles east of the city.

The State Health Department schedule requires the submission of four samples to the laboratory weekly for bacteriological analysis. The usual routine involves sample collections from the raw and chlorinated supply, which latter would include samples from the low and from the high and extra high systems. Occasionally collections are made from the so-called Penacook system, now that it is drawn from the lake and chlorinated separately. The analytical results of these examinations during the year had been uniformly good until the latter part of July. On July 11, samples from the high-service reservoir and extra high system showed coliform M.P.N. counts of 240 and greater. The matter was called to the attention of the Water Department and further sampling was conducted at the high-service reservoir. Meanwhile, the tests in the low-service part of the system were satisfactory. We realized that the bacterial test is very sensitive and it was thought that possibly the samples had been accidentally infected during the sampling process, and it was expected that the results of the second series of samples might confirm this view. At worst, since specimens from other areas of the distribution system were satisfactory, it was apparent that the pollution problem was of a local nature, affecting the reservoir section only. The second series of samples taken at the reservoir were also positive. The reason for this situation was not apparent, because the reservoir site is well located and protected by a chain-link fence about 8 ft in height, which is kept locked and is topped with strands of barbed wire. The banks of the reservoir are sloped

so as to divert away any surface wash that occurs and there did not appear to be any opportunity for contamination of human origin at this point.

In this stage of the investigation a series of samples, eight in number, was taken from various points in the reservoir on July 23. Also at this time specimens were taken from the booster station and a number of homes along the extra high-service system. The results of all tests indicated counts of 240 coliform organisms or even greater. Very careful inspection was made around the reservoir and it was finally determined that a few individuals had been gaining access to the reservoir either for fishing or bathing purposes. The evidence indicated that these people, still unknown to us, had driven a car close to the wire fence and had scaled it by means of an improvised wire ladder, which could be straddled across the top of the barbed-wire strands. The reservoir was immediately taken out of service, emptied, cleaned and disinfected. Meanwhile, samples collected as of July 27th and 30th, after the cleaning operation, were unsatisfactory, but the gravity system continued to be clear of contamination. Although the cleaning and disinfection operation was thought to have been adequately completed, the only assumption could be that the disinfection dose was not sufficient to eliminate all coliform bacteria. Therefore, on August 2, the disinfection process was repeated, with much heavier dosages of chlorine. Immediately thereafter bacterial samples were taken from the reservoir and these were satisfactory.

However, a group of samples collected on the following day from all portions of the system, the results of which were available on Monday, August 6th, were strongly positive, almost all being in the range of 240 coliform bacteria per 100 ml. It was now indicated that, although the disinfection operation at the reservoir had been effective, contamination at the main source of supply had developed and the immediate inspection made of the watershed area around Penacook Lake revealed a number of human fecal deposits, especially in the vicinity of the so-called Pavilion area, which is situated at the southeast corner of the lake, opposite the screen house serving the intake line. In all fairness it should be said that the water department has not been unaware of this hazard. In fact, on several oc-

casions the former Board of Water Commissioners had recommended to the City Council that the Pavilion be discontinued and all recreational activity in and about the lake substantially reduced or eliminated, but no action had been forthcoming. It was clearly evident even from casual observation of the pavilion site that extensive picnicking was a general practice and that people thus frequenting the area had made rather generous use of the surrounding wooded lands for toilet purposes. Under the unusual weather circumstances which we had this last summer, where it seemed to be raining almost every other day, conditions were excellent for the rapid delivery of washings from the fecal matter, deposited on the adjacent shore area directly into the lake.

Although the intake pipe several years ago was extended far into the lake beyond the screen house, it was now suspected, and later confirmed by hydraulic analysis, that leakage into the screen house was a factor. Since the greater percentage of the contamination was discharged to the lake immediately opposite the screen house, it was only a matter of a very short time before the contaminating material was taken into the supply main, because of the leakage condition and also by means of flow toward the intake as a result of wind action.

Chlorination is the only treatment employed in conjunction with the Concord water supply and this in the past has been accomplished by means of a Wallace & Tiernan gas chlorinator, actuated by a Venturi meter and located at the gate house, just below the dam at the lake. Records of residual-chlorine tests indicate that a combined residual of 0.25 to 0.30 ppm was maintained. However, the bacteriological record of samples taken during this period demonstrates that this was insufficient to destroy the large slugs of pollution which were discharged from the picnic area into the supply during this time of heavy contamination.

The seriousness of the situation now required that the public be notified that the supply was not safe for drinking purposes unless boiled. Our inspections at the lake were completed about 6:00 p.m. on Monday, August 6th, and immediately such a notice was issued to consumers by radio announcements from the local station. Meanwhile,

the chlorine dose was increased to 3.5 ppm. On August 7, an emergency gas chlorinator was installed which, with the regular unit, made it possible to inject a total of 160 lb per day into the system.

A routine of daily samples from all sections of the system was started and this plan was continued for the next several days. In the meantime, emergency chlorination facilities from the State Health Department were installed at the Concord Ice Co., which manufactures artificial ice from the municipal supply, so that the plant could continue operating.

In an attempt to hasten disinfection of the distribution system, the Soucook well system was started, with an emergency gas chlorinator installed at the well pumping station, so as to inject additional chlorine throughout the distribution layout. Including the chlorine injected into the supply at this point, the average daily dose was in the vicinity of 9-10 ppm. During night hours, when minimum flows develop, the dose approached 50 ppm. Even with these amounts of chlorine and the constant flushing of the extremities of the system, bacterial samples continued to show substantial pollution, particularly in the south and east sections of the city.

Obviously it was impractical to attempt the destruction of all evidence of contamination by heavy chlorination at the source and well station; hence two crews with emergency hypo-chlorinators began a systematic program of disinfection for the outlying areas. In our early efforts for disinfection of the South End portions of the system, we employed doses of about 15 to 20 ppm. Bacterial samples of water, taken to check the effectiveness of treatment, showed that coliform organisms were surviving in almost all instances, probably indicating that iron and organic-matter accumulations in the mains were dissipating the chlorine and preventing the destruction of bacteria. Accordingly, the dosage was increased to a minimum of 50 ppm. Even under these conditions we occasionally observed that coliforms were surviving, undoubtedly due to backflow of water from dead ends and flow into treated sections of the grid from areas which had not been disinfected. Experience throughout the incident demonstrated the extreme dfficulty which is encountered in disinfecting an entire distribution system, due to the complex manner in which flow takes

place throughout the network of pipes in the system. It certainly is not to be regarded as a simple procedure, such as the disinfection of a new main before placing it in service, where it is possible to arrange for a specific chlorine dose and a definite contact period. We were in the position of having to maintain service under variable-flow conditions and had no control over the contact period. As a result of this situation, in the East Concord and South End areas, the process had to be repeated a number of times before evidences of contamination were eliminated.

Altogether the incident involved a two-week period of constant flushing, disinfection of the outlying areas and heavy chlorination of the water at the source, before bacterial samples indicated that the system was free of contamination. In all, 600 samples were examined during the period and, in addition to the 10 water-works employees who were devoting essentially all their time to working on the problem, the State Health Department had two men working full time on the project.

With regard to our efforts to prevent future incidents similar to this one, I can say that immediately after being made aware of conditions at the pavilion, City Manager Brackett on August 7 issued public notification to the effect that the pavilion area was closed to all usage. The following week, the City Council, which under the provisions of the charter relating to the water works has full authority to take such action as may be determined necessary to protect the purity of the water supply, closed all of Penacook Lake and its shores to recreational or other activity. This temporary ban will continue in effect until the Council develops what may be regarded as permanent restrictions for the supply. In this connection the State Board of Health advocates the following measures for insuring the quality of Penacook Lake:

> "1. Experience has always demonstrated that whenever surface waters are open to use by people on recreational or other basis, inevitably, at some time, potentially serious contamination of human origin results in the waters or upon the shores thereof. Further, because pollution thus introduced can be rapidly transmitted in relatively high concentrations from even remote sections of such a lake as Penacook Lake to the water works intake structure due to the effect of wind action, it is recommended that all human activity

be discontinued upon the Lake. The only exception to such restriction should be that which would allow employees on and about the waters of the Lake in the performance of necessary duties for the protection and control of the water supply.

"2. Recreational use of Russell Pond area tributary to Penacook Lake should be abandoned since available records and studies by competent engineers have demonstrated the hazard which has resulted to the water supply by virtue of the Russell Pond Development.

"3. The City should continue to pursue its policy of purchasing shore lands around the lake so that this program may be completed at the earliest feasible time.

"4. The City should immediately establish an adequate and systematic patrol so that watershed conditions may be observed. In order that the patrol may serve as a basis for enforcing restricting regulations duly adopted by the City Council, the personnel thus employed should be empowered to enforce such regulations.

"5. Present-day good water works practice requires the covering of open reservoirs or chlorination of all water delivered therefrom into the distribution system. Although the high pressure reservoir is provided with suitable fencing and periodic visits are made to observe and maintain sanitary conditions at this installation, the fact remains that the structure is not covered. So that the supply may be protected from contamination at all times it is recommended that chlorination facilities be installed at this location."

The matter is now in the Council's hands and it is expected that definite action will be forthcoming sometime in the near future.

Conclusions regarding Management of Surface Sources from a Sanitary Standpoint

While the problem was one that we would have preferred to avoid, there are certain valuable experiences that have been gained, which can be summarized as follows:

(1) Chlorination treatment of itself should be regarded solely as a safeguard or precautionary measure and not in any way should it be thought of as a means for controlling more than minor chance pollution. Simple chlorination, such as is commonly practiced in this area, involves chlorine residuals whose capacities for disinfection can easily be exceeded. That this is the situation is amply demonstrated in the case of Concord. To be sure, breakpoint chlorination, which involves the use of higher chlorine residuals, will permit a greater

degree of raw-water contamination. Obviously, however, the disinfection capacity of this practice can be exceeded, provided that the extent of contamination is sufficient, and it is very doubtful that any appreciable increase in recreational activity around a water supply is warranted on the basis of the superior disinfection powers of breakpoint chlorination. Moreover, breakpoint practice produces a more corrosive water, and the taste and odor problems which develop as a result of its use are important factors to consider. The significant consideration to bear in mind, in the control of waters which are subjected to chlorination treatment only, is that the watershed area must be maintained in a clean condition and it is of particular importance that the use of shore areas and waters of the supply intake reservoirs be restricted against human activities. Experience indicates that so long as such waters are available for recreational or other human use, serious contamination is bound to result, either regularly or intermittently. While in theory we may entertain the idea of multi-purpose use of water-supply intake reservoirs under conditions of adequate chlorination and careful supervision by sanitary patrols, the evidence demonstrates the impossibility of attaining adequate supervision and chlorinators are subject to mechanical failure, as we all know. About all that can be accomplished by the use of patrols is the suppression of excessive abuses. There will always be those careless individuals who do not observe the need for maintaining water quality and the pollution that is occasioned because of their attitudes and actions unfortunately cannot be prevented, except by a complete ban against the use of intake reservoirs.

To my knowledge, until recently very little attention has been given to the transportation effect of wind action on pollution in surface waters. The dilution and gradual destruction of bacterial contamination that do occur, as a result of displacement by flow toward a reservoir or lake outlet, are not an important influence in controlling raw-water quality. The governing factor, unfortunately, in transferring pollution from one point to another is the movement of water produced by wind action.

During the summer of 1950 float-test measurements to evaluate the effect of wind action were made at the Manchester supply under

the direction of Thomas R. Camp, of Camp, Dresser & McKee, Consulting Engineers, Boston, Mass. While I am not going to elaborate on the details of these tests, it should, however, be stated that during the process both surface and sub-surface floats were used, the latter so designed as to be able to measure wind-induced velocities at several depths under varying weather conditions. The main observation to bear in mind in connection with these studies is that a moderate wind, blowing across a lake, will produce surface currents equal to 2-3% of the wind velocity. Thus, a wind of 5 miles per hour will transport the surface water of a lake toward the intake at an average of 660 ft per hour, when the wind is in the direction toward the intake.

Chip tests were also made, in order to determine the angle at which contaminating material disperses as a result of wind action on surface waters. This was found to be in the range of 4 to 6 degrees. Hence it is obvious that fecal pollution introduced in a surface water can, under proper wind conditions, be transferred rapidly from the point of introduction toward the supply intake in dangerous concentrations. The Manual of Recommended Water Sanitation Practice, Public Health Bulletin, No. 296, dated 1946, recommends for waters requiring simple chlorination or its equivalent that the coliform bacterial content should not exceed 50 organisms per 100 ml in any month. Using this recommended standard, Camp has established, in the case of both the Manchester and Concord supplies, that the fecal discharges from only a few persons, if permitted to enter the lake, will probably cause pollution at the supply intake within a relatively short period of time. The same conclusions in general apply to all intake lakes or reservoirs. These considerations demonstrate the fundamental necessity for restricting human activity in and around surface water used directly for water-supply purposes. Increasingly, the proposal is being advanced that intake surface sources can be used for recreational and other purposes, provided that filtration systems are installed. While, of course, greater degrees of raw-water contamination can be tolerated where filtration is in use, it must be pointed out that even under these circumstances pollution can become so great as to make treatment difficult or unsatisfactory.

It should be noted here that Harold W. Streeter, in reinvestigating the allowable limits for raw-water contamination in waters used for potable supplies, concluded that the most probable number of coliform organism in waters of the Ohio River at water intakes should not exceed 5,000 per 100 ml in any month, nor exceed this number in more than 20% of the samples of such waters examined during any month, nor exceed 20,000 per 100 ml in more than 5%of such samples. Basically these are the same recommendations that are advocated by the U. S. Public Health Service and are in agreement with earlier studies by Streeter 20 or more years ago. In his report to the Ohio River Valley Water Sanitation Commission, who engaged him as a consultant to investigate bacterial quality objectives, it is pointed out that there have been no significant advances in the art of filtration during the last 25 years and that the over-all effectiveness and increased efficiency of treatment are due to improved chlorination practices—this latter, of course, accompanied by deterioration in the quality of water supplies except for bacterial content.

(2) The Concord incident again pointed up very strongly the weakness in present methods for the detection of pollution in a water supply. The best procedures we have today are, of course, the bacterial tests, particularly the tests for coliform organisms. In the case of Concord, samples are received in the laboratory on the same day on which they are collected. With regard to practically all other water supplies in the State, the samples are a minimum of a day in transit before reaching the laboratory. Present practice now requires performing the confirmed test, as well as the regular presumptive test. Each of these examinations, as you are aware, involves a minimum of 24 hours and a maximum of 48 hours before the results are available. Obviously, then, for the average supply, if pollution be present, existing laboratory methods cannot disclose the condition until after a lapse of three to five days. While the coliform test is an effective method for demonstrating the presence of intestinal bacteria with, of course, the assumption that, if these organisms are in the water, there is likelihood of the presence of disease-producing bacteria also, the time element is so unfavorable that an epidemic could occur before the laboratory findings would demonstrate the existence of con-

tamination. Because of this serious limitation in evaluating the efficiency of treatment, we believe it to be highly essential that all reasonable precautions be taken to protect the water quality of supplies which are treated by chlorination only.

Although a typhoid epidemic did not result in the case of the Concord water supply, from inquiries made by the State Health Department of physicians practicing in this city, it is clearly evident that there was a sharp increase in the incidence of gastro-intestinal upsets, coincident with pollution of the water supply. Except for amoebic dysentery and typhoid and paratyphoid fevers, all other enteric diseases are not reportable by physicians in New Hampshire. Hence, it was impossible and no attempt was made to obtain any accurate estimate as to the number of cases developing. However, it is acknowledged that the outbreak was widespread and, in my opinion, attributable to contamination of the supply.

In a report on a study of the potential public-health hazard in connection with the opening of portions of the Manchester water supply for recreational activity, Dr. S. L. Chang of the Harvard School of Public Health commented as follows in regard to the total number of cases of typhoid and paratyphoid fever reported in the United States during the period from 1940 to 1950:

"It should be noted that while there has been a gradual but steady decline in the incidence of typhoid and paratyphoid fever during the eleven-year period, this has not been paralleled by a decline in the incidence of these infections in water-borne outbreaks. Furthermore, the incidence of these infections in water-borne outbreaks, as will be shown in the next section of this report, fluctuated irregularly during this period, indicating that most, if not all, of these outbreaks were accidental in nature and were therefore not unavoidable."

Further, for the period 1938 to 1947, he analyzed the total number of water-borne outbreaks of enteric infections, as well as the total number of cases occurring during each of these years. From these data it is apparent that both the number of water-borne outbreaks and the number of cases involved each year, during the ten-year period ending in 1947, were irregular and showed no trend

toward decline. In summarizing available data relative to water-borne enteric infections, Dr. Chang made these observations, as contained in the Manchester report:

"While we are living in the most sanitated environment on earth, we are by no means free from any of these infections that plagued us before the environment was brought under sanitary control. Since 1940, we have been having annually 3,000 to 5,000 cases of amoebic dysentery and 20,000 to 40,000 cases of bacillary dysentery. Although there has been a gradual decline in typhoid and paratyphoid incidence, there were still over 3,000 cases in 1950.

"In the 10-year period ending in 1947, we had a total of 393 water-borne outbreaks of enteric infections, involving a total of 128,335 cases. At present we are threatened by 5,000 to 6,000 cases of water-borne origin a year."

If it is borne in mind also that the cases reported are probably but a small fraction of the total occurring, it seems apparent from Dr. Chang's study that there is no sound basis for relaxing restrictions against recreational activity in and about surface waters which are treated by chlorination only.

In conclusion, it is perhaps worthy of mention that the cysts of amoebic dysentery and the virus causing infectious hepatitis are resistant to chlorine. This is particularly serious in regard to amoebic dysentery, where the dosage required for destruction of the organism lies within the super-chlorination range and the dose necessary to kill the virus is higher than that normally used in water-works practice. Obviously protection against these diseases in a supply which is treated by chlorination only will not be possible, unless the intake source is restricted against human activity. Perhaps one of the most significant facts disclosed by the Manchester water-supply study is that when human activities were restricted in the intake-reservoir area, the raw-water coliform counts came well within the recommended limit of 50 per 100 ml, as contained in the "Manual of Recommended Water Sanitation Practice" for water supplies subject to treatment by simple chlorination only. The Manchester supply was closed to all human activity for two periods, one during the recent World War and the other for approximately a year and one-half, beginning in 1949, when

the State Board of Health had in force regulations prohibiting resort to the use of the lake waters for recreational or other purposes. During other periods, when fishing, boating, etc., were permitted even to a limited degree, we periodically experienced coliform counts in excess of the recommended standards for raw-water quality, thus reflecting the sporadic or intermittent type of pollution that will develop in surface-water supplies available for recreational or other use. The fluctuating nature of coliform counts which develop under these circumstances is highly significant, since it is a direct indicator of the dangers which arise, due to the transportation effect of wind action on pollution introduced into a surface water supply.

THE NEW GAS TRANSMISSION LINES IN MASSACHUSETTS IN RELATION TO PUBLIC WATER SUPPLIES

BY RALPH M. SOULE*

[*Read December 20, 1951.*]

In recent months, the supplying of natural gas to Massachusetts and other New England States has been receiving considerable publicity. The natural gas for this area will come from an extensive area along the coast of the Gulf of Mexico, extending from the Mississippi River to the Rio Grande River. It has been reported that 70% of the natural gas reserves of the United States are located in this area and additional reserves are being discovered at frequent intervals. In some cases, wells are drilled in coastal waters at locations from 10 to 15 miles offshore. Geologists have estimated that oil- and gas-producing areas may extend as far as 50 to 75 miles offshore.

Until fairly recent time, it was apparently uneconomical to transmit gas through a pipe-line for any considerable distance, due to the high cost of materials and relatively low operating pressures. The introduction, however, of a thin-walled steel tubing, capable of withstanding unusually high pressures, probably led to the development of natural gas transmission as it is being practised at the present time.

Natural gas is now utilized in 40 of the 48 states through more than 250,000 miles of pipe-lines. The natural gas transmission pipe-lines operate at pressures of 750 to 1,000 lb per square inch. Each line is constructed as a solid, welded steel tube and even the valves are built of cast steel with welded ends, so that no flanged joints are necessary. Electric welding techniques have been developed to a point where the welded joint is always stronger than the pipe-line. Pipe-lines are laid to a depth sufficient only to provide protection from vehicles and ordinary use of the ground. In order to protect against corrosion, the pipes are coated with various types of protective materials, principally coal-tar enamel. Cathodic protection installations are also made at certain locations along the pipe-line, in

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order to effect further protection against corrosion. When such installations are made, the two principal methods are: the installation of zinc, magnesium or carbon anodes, which provide their own potential difference between the anode and the pipe-line; or the installation of steel or cast-iron ground beds, where the potential difference between the ground bed and the pipe-line is provided by an outside source of electrical energy.

It is estimated that the modern pipe-line, properly protected, will have an indefinite life, inasmuch as there is a minimum of internal corrosion and external corrosion is positively controlled.

At the present time there are two companies engaged in the construction of gas transmission lines, for the purpose of supplying natural gas to many communities in Massachusetts.

The Northeastern Gas Transmission Co. has installed a main line across the State from the town of Richmond, extending south of the city of Springfield up to Burlington, Mass. (see Fig. 1). The larger laterals extend from this line toward North Adams and Pittsfield, Northampton, Springfield, Fitchburg, Worcester, Haverhill, Gloucester and Lynn. A 16-inch connecting main is connected to the main line in the town of Agawam, southwest of Springfield.

The Algonquin Gas Transmission Co. is engaged in the construction of a 24-inch line, extending from the town of Uxbridge northeasterly to Lexington, with laterals extending to Everett, Braintree and Brockton, and through Rhode Island to Attleboro, Taunton, Fall River, New Bedford, Plymouth and Cape Cod (see Fig. 1).

The possible effect that these gas transmission lines might have on public water supplies in Massachusetts was first called to the attention of the Department of Public Health in connection with the preliminary surveys being made for the construction of these lines in the vicinity of the ground-water supply of the Lynnfield Center Water District. Upon investigation it was learned that, before any gas pipe-line could be laid in Massachusetts, it was required that a hearing on the matter be held by the Department of Public Utilities for the purpose of obtaining information as to the necessity for acquiring land and easements by eminent domain. Since it was obvious

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC HEALTH
NATURAL GAS TRANSMISSION LINES
CONSTRUCTED AND PROPOSED

FIG. 1.

that other states, particularly those in the midwest, must have had experience with gas transmission lines in connection with water supplies, the office of the Division of Sanitary Engineering of the Massachusetts Department of Public Health inquired of the state sanitary engineers of certain of the midwestern states as to their experience in this matter. In general, it may be said that these states did not consider the installation of such gas transmission lines a hazard to any of their public water supplies. Typical of our New England conservatism, however, the Department of Public Health considered it advisable to study the matter very carefully.

Through the courtesy of the Tennessee Gas Transmission Co. and the Northeastern Gas Transmission Co., samples of gas were sent to the Water and Sewage Laboratory of the Department of Public Health for analysis and experiment. The analysis of the gas was found to be very similar to the analysis furnished by the Tennessee Gas Transmission Co. The results of this analysis are as follows:

Analysis:	Mol (%)
Carbon Dioxide	0.40
Nitrogen	0.21
Methane	94.40
Ethane	3.37
Propane	0.98
Iso-Butane	0.17
N-Butane	0.19
Iso-Pentane	0.05
N-Pentane	0.04
Hexanes	0.13
Heptanes Plus	0.06
	100.00

Moisture Content ..... 7.48#/MMCF
Sp. Gr. at 60°F. and 14.696 PSIA (AIR = 1), 0.5987
B.T.U./Cu Ft at 60°F. and 14.73 PSIA:
Dry Basis 1,066
Wet Basis 1,047

Mr. Rubin, Chief of the Water and Sewage Laboratory, made certain experiments with the samples of gas submitted. It was found that the odor of the natural gas was a faint, sweetish hydrocarbon

odor, similar to benzol. Samples of water were allowed to be in contact with the gas under normal temperature and pressure, and determinations were made of the intensity of the odor of the water after various periods of contact. In making determinations of the relative intensity of the odor the results were expressed in terms of threshold-odor number. This is determined by adding to odor-free water varying amounts of the sample to be tested. The total volume of the dilution, divided by the volume of the sample in the dilution which gives the first perceptible odor, is called the threshold-odor number. The threshold-odor number of waters in Massachusetts varies between 0 and 3. With volumes of gas three times that of the volume of water, odor was absorbed by the water to the extent that threshold-odor numbers as high as 5 were observed after a period of contact of one to five days. Experiments were also made by bubbling gas through a layer of water, to simulate conditions in the field where a gas pipe-line might be laid in a swampy area, covered with water, and a ground-water supply taken from the general vicinity. These experiments were carried out with water at a temperature of 50°F., which is about the average temperature of ground waters in Massachusetts. Determinations were made of the intensity of the odor after various volumes of gas had bubbled through the water.

The results of these experiments showed that with increasing volumes of gas up to five times the volume of water and contact periods varying from one to five days, the threshold-odor number varied from 20 to 25. Somewhat higher threshold-odor numbers were obtained when the same experiments were conducted on water with a temperature of 75°F. Since all natural gas must be artificially odorized before being discharged into the State, similar experiments were conducted on this odorized gas. The odor of the odorized gas was somewhat different in character, being less sweetish, but appeared no stronger than unodorized gas.

The results obtained with the odorized gas were practically identical with those obtained from the experiments in which unodorized gas was used, when the gas from an overlying atmosphere was absorbed by the water. When the gas was bubbled through a layer of water, threshold odors as high as 10 were obtained, even when the volume of gas was equal to the volume of the water.

The results of the experiments indicated that natural gas present in an atmosphere will impart an odor to the water. It was evident from the tests that, when natural gas is in contact with potable water, an odor similar to benzol is imparted to the water. The intensity of this odor is dependent upon the volume of gas, the volume of water and the period of contact. Under certain conditions the odor is sufficiently great to render the water unpalatable. Chlorination of the water which has been in contact with natural gas has little effect on the character of the odor of the water, the resulting odor being a mixture of natural gas and of free chlorine.

Data available to the Division of Sanitary Engineering of the Department of Public Health show that the companies which are engaged in laying gas transmission lines throughout the State are taking unusual precautions to prevent accidental explosions and leakage of gas. The pipe is all of steel with welded joints, treated with a priming coat, enamel, and wrapped with asbestos felt or glass fibre, saturated with coal tar. This treatment of the exterior of the pipe satisfactorily protects it from corrosion. The general procedure is to join the sections of pipe together on the shoulder of the trench and lower it into the trench with special equipment in such a manner as to prevent scraping off the protective coating.

After the joints have been welded, they are subjected to an x-ray examination. Following completion of the pipe-line construction, a test is made on each section of the line and it is subjected to a pressure of 1,000 lb per square inch. Where the pipe-line passes under important highways and streams, it is laid in a special steel sleeve, having a thickness of at least $\frac{3}{8}$ of an inch.

In order to establish general requirements, the Department of Public Health has recommended that no gas transmission line should be located within 400 ft of any well used as a source of public water supply or within 50 ft of high-water mark of any surface-water source of supply or tributary thereto, without special approval of the Department. The observance of these requirements should provide adequate safeguards for public water supplies against contamination from gas transmission lines. Some of the typical experiences which the Division of Sanitary Engineering has had in connection with the lay-

out of the proposed pipe-lines with relation to public water supplies are as follows:

Monson

A 24-inch gas pipe-line as it passes through Monson crosses South Brook, which is tributary to a dug well, and Conant Brook, which is tributary to the emergency source of water supply of the town. Because of the grade conditions at this location, it was more feasible to encase South Brook across the right-of-way of the gas transmission company for a distance of about 150 ft rather than install the special steel casing on the gas transmission line. A ⅜-inch steel pipe was used to case the brook. At this particular location this solution was the better one, since in case of trouble any repairs could be made to the gas line much more readily and the brook could remain in service during any such repair.

Lowell

The original layout of the gas transmission line to the city of Lowell passed very close to certain wells used by the city of Lowell as sources of water supply. After various conferences with city officials and representatives of the gas transmission company, an alternate line was selected, which would locate the line at a greater distance from the wells and in ground which was at a considerably higher elevation than the ground at the wells. In case of leakage under these conditions the gas could not affect the water supply of the city of Lowell. In the various considerations of this problem it was considered at one time to lay the gas transmission line on concrete piers above the surface of the ground. The alternate location selected eliminated the necessity for this rather objectionable construction.

Hamilton

The layout for the gas transmission line to Gloucester passed through the well field of the town of Hamilton. The elevation of the ground at this point was only slightly above the ground-water table. It was felt that the gas transmission line would be particularly hazardous to the water supply of the town of Hamilton. After giving it considerable study, the line was changed so that the pipe-line would be laid in an abandoned railroad right-of-way, where the elevation

would be somewhat higher than the elevation of the swamp and the maximum flood-water level in the swamp.

Cambridge

The layout for the gas transmission line through Waltham and Weston passes through the northerly end of Stony Brook Reservoir, one of the sources of water supply for the city of Cambridge. The portion of the reservoir through which this line passes, formed by the construction of the new Route #128, is connected to the remainder of the reservoir by a conduit.

While the hazard to the Cambridge water supply from the location of the gas main underneath the reservoir at this location is not great, it was believed that a more desirable location would have been within the highway location of Route #128 and above the high-water mark of Stony Brook Reservoir. It was impossible, however, to obtain a permit from the Massachusetts Department of Public Works to locate the line within the limits of this new highway. The pipe-line beneath Stony Brook Reservoir and for a distance of 50 ft from the high-water mark of the reservoir will probably be laid in a special steel casing, having a thickness of one-half inch and provided with vents at either end of the casing.

Wellesley

The proposed location for the gas transmission line through Wellesley passed through the well field of the town of Wellesley, adjacent to Rosemary Brook. The location of the line at this point presents a hazard to this source of water supply of the town of Wellesley and conferences are now under way to effect a change in the location of the line, so that the pipe-line will be at least 150 ft from the nearest well of the water-works system. In the event that the pipe-line is located within 200 ft of any well, it is probable that the company will be required to encase the main in a special steel casing for a distance of perhaps 400 ft from the nearest well.

The author wishes to acknowledge assistance given to him in the preparation of this paper by representatives of the Massachusetts Department of Public Utilities, by Mr. Rubin of the Water and Sewage Laboratories and by members of the staff of the Division of Sanitary Engineering of the Department of Public Health.

RECENT IMPROVEMENTS TO THE WATER-SUPPLY WORKS OF MANSFIELD, MASSACHUSETTS

BY L. M. PITTENDREIGH*

[*Read December 20, 1951.*]

The water-supply works of the town of Mansfield was chosen for the subject of this paper because it is believed there are not many towns of comparable size and population in New England which supply one industry with such a large percentage of all the water pumped by the town—nearly 70%. In less than a year's time the water consumption has nearly doubled. Kittery, Me., is another town where one customer, the Portsmouth Navy Yard, takes about 50% of all the water consumed, but the town does not have to pump all of it; theirs is a gravity system. However, Mansfield does, and therefore I should like to relate the events and steps which it has taken to cope with the situation. With the decentralization of manufacturing and the "mushrooming" of plastic industries, it is possible that many superintendents and water-works men will be confronted with the same problem.

Mansfield is about midway between Boston and Providence on the Providence division of the New Haven Railroad. The town contains several industries: namely, a Division of the Hercules Powder Co., the Lowney Chocolate Co., the National Gypsum Co., the J. L. Clemmey Co. (manufacturers of steel tanks) and the Mansfield Bleachery.

Prior to 1949 the water supply for the town of Mansfield was derived from a large dug well, 30 ft in diameter and 20 ft deep, located on the site of what was once called Cate's Spring. This well is in the northeast part of the town, on the watershed of the Canoe River. The area of watershed lying upstream from the well is about 3¾ sq mi and consists of large gravel deposits, as witnessed by the numerous gravel pits. This well was constructed in 1888 and water

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was pumped into the distribution system by means of steam-driven pumps until 1937, when a two-stage centrifugal pump was installed. The pump has a 100-hp electric motor on one end of its shaft and a gasoline engine on the other end. The capacity of the pump is about 900 gpm, depending upon the water level in the large dug well.

Situated on what is called "Foolish Hill" in the neighboring town of Foxborough is a large underground reservoir, with a capacity of 1.55 mil gal and a water depth of 12 ft or 130,000 gal per ft. This reservoir is Mansfield's only storage facility and was constructed in 1914. The distribution system comprises about 52 miles of water mains, ranging in size from 6-in. to 14-in., and serves a population of approximately 7,200.

In 1944 Whitman & Howard were employed by the town, through its Town Manager at the time, James L. Shurtleff, to investigate the possibility of increasing the yield of the old Cate's Spring dug well. Test wells were driven adjacent to the large dug well and the results showed that the total depth of overburden was 42 ft 6 in.; coarse sand and gravel comprised the lower 30 ft. This indicated that excellent water-bearing material existed 23 ft below the bottom of the large dug well. From this it was concluded that a gravel-packed well could be constructed to about 42 ft and additional water could be pumped from the area.

As a result of the investigation it was recommended that such a well be installed, with a vertical turbine pump having a capacity of about 1,200 gpm. The Superintendent and the Manager pleaded for this additional water, but no appropriation was made and the matter was dropped.

In the summer of 1949, this area experienced the worst drought on record. The water level in the large dug well dropped continually. During the first part of August the aforementioned centrifugal pump had to be throttled to 618 gpm, but continued to pump 24 hours a day; the reservoir was at a dangerously low point. A state of emergency was declared by the acting Town Manager, John D. Prescott, and was recommended by the State Department of Public Health. The Manager ordered a gravel-packed well constructed at the location tested in 1944. The D. L. Maher Co., which had made the original tests, was employed to do the work.

Construction of the well began on the 19th day of August, 1949, and was completed on Sept. 1st. Temporary pumping equipment was installed and water was being pumped into the large dug well the following day. Of course, this measure was used only to relieve the immediately critical situation and to keep the suction of the centrifugal pump flooded until the reservoir could be filled. In the meantime a 12-in. tapping sleeve and valve were installed in the suction pipe from the dug well, to provide a means of boosting the water directly into the suction system, instead of wasting a large amount in the well; for that was what was actually happening.

One interesting feature in connection with discharging the water into the large dug well was the method the well contractor used to prevent agitation of the material at the bottom of the well. Instead of letting the full 8-in. stream of water fall directly into the well to the water surface 18 ft below, he suspended a 24-inch louvre-type well screen horizontally and discharged the water directly into it. The shutter openings in the screen were directed toward the stream of water and these caused the water literally to "rain" down on the water surface below. By this method the pumping of water into the distribution system with even slight turbidity was prevented.

In November of that year we were authorized to make an investigation of the probable requirements for additional water, together with determining its availability and location.

The yield experienced during the drought in the Cate's Spring area proved that the Canoe River watershed would be inadequate to supply any marked increase in consumption. It was therefore decided not to build the permanent works over the emergency gravel-packed well at this time, but first to establish an additional source and then to carry out the entire work in one project.

The town of Mansfield is located at the top of the watersheds of the Canoe, Rumford and Wading Rivers, and a portion of the Bungay River. From the geological aspects of the area we expected to find the depth of overburden throughout the territory to be shallow. In planning the location of test wells a study of the geology of the region was made and test wells were driven on each of the watershed areas. Some water was found to be available in all of the test wells driven.

A few test wells were driven on the watershed of the Canoe River, downstream from the existing works, in an attempt to find a greater depth of water-bearing material which would permit pumping from greater underground storage, but it was apparent that the Canoe River source of supply was already located in the deepest deposit of sand and gravel and so contained the greatest amount of underground storage.

Five test wells were driven on the Rumford River watershed, but the overburden was found to be shallow and of poor water-bearing quality. The water also was found to contain iron.

Nine wells were driven on the Wading River watershed. Again the overburden was found to be shallow, being about 25 ft in depth. However, while all of these wells did pump some water, the depth of water-bearing material was found to be not more than 2-3 ft thick in a stratum directly above the ledge or bed rock.

Five wells were located on the Bungay River shed. Here the depths ranged from 35 to 40 ft and all wells were found to contain excellent water in an excellent water-bearing sand-and-gravel stratum. They were located in the vicinity of Greenwood Lake, which is considered the source of the Bungay River.

A pumping test was conducted in the latter area by means of driving a group of six 2½-inch wells, connecting five of them together and pumping them at a rate of 230 gpm 24 hours a day for 7 days. As a result of the test, it was determined that an additional 1 mgd could be obtained from this area by means of two low-velocity gravel-packed wells. The water quality during the test was found to be the same as from the existing dug-well source. The town distribution system did not reach the northwest corner, where this supply was found; therefore the installation of 3½ miles of mains was necessary to get this water into the heart of the distribution system.

The West Mansfield supply was finally developed by means of two gravel-packed wells, numbers 2 and 3, having a capacity of 450 gpm and 250 gpm, respectively, and situated about 250 ft apart.

Over gravel-packed well No. 1 (the emergency well) a pumping station was constructed, and pumping equipment was installed having a capacity of 1,260 gpm under average water-level conditions.

Gravel-packed well Stations Nos. 1 and 2 have gasoline-engine standby equipment as well as the regular electric-motor-driven equipment. The entire project, which has more than doubled the capacity of the water-supply works to 2.8 mgd, cost $125,000. The project was begun under Acting Manager Prescott, completed under the present Manager Ervin Welch and guided throughout by Mr. Albertini, who has been Superintendent of the Water Department for 10 years.

As mentioned before, Mansfield is in a class by itself when it comes to water consumption. The total gallonage pumped in 1949 was in the neighborhood of 351,000,000, or about 0.9 mgd; in 1950 it was nearly 459,000,000 gallons, or an average of 1.26 mgd; the amount estimated for 1951 is 752,000,000 gallons, or an average of 2.2 mgd. Figure 1 shows the situation graphically.

In 1949 the one large user, the Hercules Powder Co., used 39% of all the water pumped. In 1950 they used 56.5% of all the water pumped and it is estimated that for 1951 they will have used 68% of all the water pumped. Some months they used as much as 75%. The manufacture of the product made by this industry involves cooling and it can be seen that the process requires a tremendous amount of water. The figures also show that the use of water by this industry governs the amount of pumping done by the town.

The new 1-mgd supply in West Mansfield is operated 24 hours a day, 7 days a week, with no attendants. The 1.8-mgd pump in gravel-packed well Station No. 1 is operated sometimes by a time clock between the hours of 7:00 A.M. and 11:00 P.M. daily and sometimes 24 hours a day.

There is close coöperation between the large user and the town. Evidently the use of water in the manufacturing process is quite elastic and can be varied considerably. Hercules seems to regulate its use of water both by the level of the water in the reservoir and by consumption demand of the town itself. A representative from the company checks on the town's flow gauges and water-level gauges almost daily.

No doubt you may be interested in the revenue received from such a customer as Hercules. The rate is based on $0.10 per 1,000

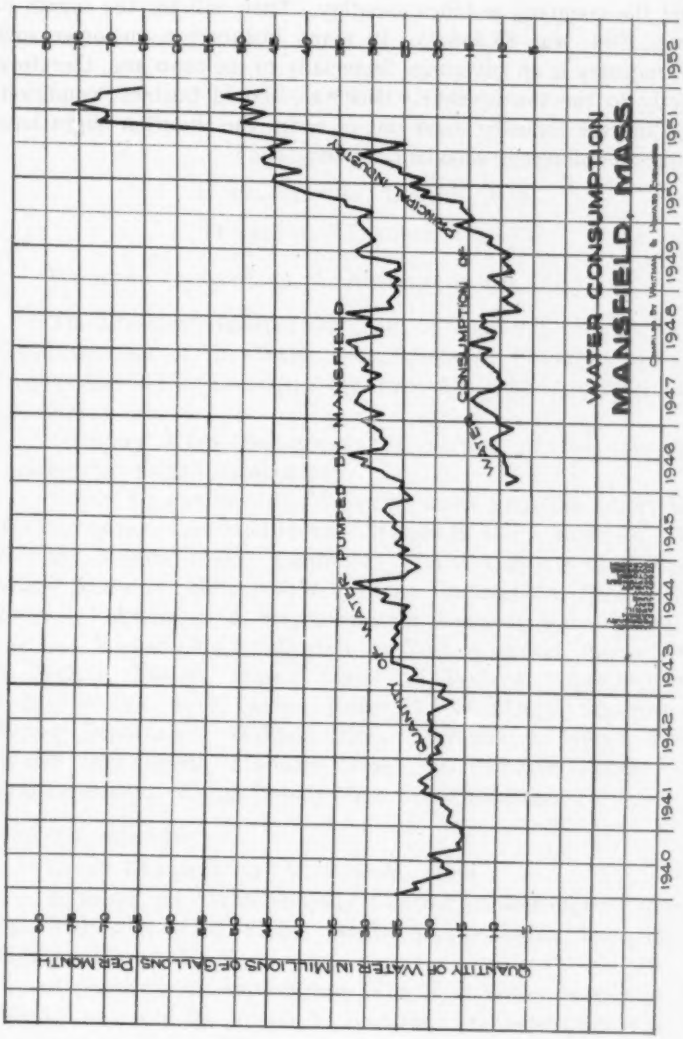
WATER CONSUMPTION
MANSFIELD, MASS.
Compiled by Whitman & Howard, Engineers
QUANTITY OF WATER IN MILLIONS OF GALLONS PER MONTH
QUANTITY OF WATER PUMPED BY MANSFIELD
WATER CONSUMPTION OF
PRINCIPAL INDUSTRY
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952

FIG. 1.

gal and the company is billed monthly. Their bill for the month of October, 1951, was $5,388.93. In many instances a customer such as this industry is an advantage financially to the town and, therefore, indirectly to the townspeople. However, should business conditions change and the industry move out of town, the situation might have an altogether different economic aspect.

PROCEEDINGS

FEBRUARY 1952 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, FEBRUARY 14, 1952

President Frederick O. A. Almquist in the Chair.

The President reported the death of Charles J. Crump, formerly Superintendent of the Water Department of Franklin, Mass. Mr. Crump joined the Association on June 27, 1922, and died January 24, 1952.

Secretary Knox announced the election of the following to membership in the Association:

Edwin C. Bradley, Jr., Superintendent and Treasurer, Bourne Water District, Cataumet, Mass.; Harold E. Cady, Engineer, Metcalf & Eddy, Boston, Mass.; Charles O. Clark, Associate Civil Engineer, Water Division, Metropolitan District Commission, Boston, Mass.; Patrick J. Flynn, Sales Representative, Kennedy Valve Manufacturing Co., Waban, Mass.; Darrell A. Root, Engineer, Camp, Dresser & McKee, Boston, Mass.; Leslie M. Willard, Superintendent of Public Works, Ayer, Mass.; Robert F. Woodbury, Superintendent, Water Department, Halifax, Mass.; William J. Hynes, Methuen Water Department, Methuen, Mass.; E. Edward Faenza, Acting Superintendent, Water Department, Franklin, Mass.

Associate Member:

Lovell Chemical Co., Watertown, Mass.

A paper on "Water-Supply Control in Retrospect" was read by Charles R. Cox, Chief, Water Supply, State Department of Health, Albany, N. Y.

A paper on "Establishment of a New Water Supply at Essex, Mass." was read by Joseph N. Farnham, Jr., Superintendent, Water Department, Essex, Mass.

A paper on "Direct-Suction Gravel-Packed Well at Hanover, Mass." was read by Howard E. Bailey, Consulting Engineer, Boston, Mass.

MARCH 1952 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, MARCH 20, 1952

President Frederick O. A. Almquist in the Chair.

Secretary Knox announced the election of the following to membership in the Association:

Richard F. Dutting, Engineer, Centriline Corp., Hawthorne, N. J.; Charles F. Kennedy, Senior Civil Engineering Aid, Water Division, Metropolitan District Commission, Boston, Mass.; Charles F. Kent, Superintendent, Water Department, Tewksbury, Mass.; William Neal MacKenzie, President and Treasurer, Terryville Water Co., and General Manager, Naugatuck Water Co., Naugatuck, Conn.; Vincent J. Petroccia, Superintendent of Water, Oakville Fire District, Oakville, Conn.; John K. Donnelly, Superintendent, Water Department, Harwich, Mass.

Associate Member:

Donnelly Products Co., Malden, Mass.

Upon motion duly made and seconded, it was VOTED to appoint the following as a Nominating Committee: Arthur C. King, Donald C. Calderwood, Arthur L. Shaw, Harold W. Griswold and Karl R. Kennison.

A paper, entitled "The Ever Lengthening Shadow", was read by Ralph M. Binney, Vice-President, First National Bank of Boston, Boston, Mass.

A paper on "Operation of the Dennis Water District" was read by Gordon A. Barker, Superintendent, Dennis Water District, Dennis, Mass.

A paper, entitled "The Water-Works Industry Needs a Safety Program", was read by Raymond J. Faust, Executive Assistant Secretary, American Water Works Association, New York, N. Y.

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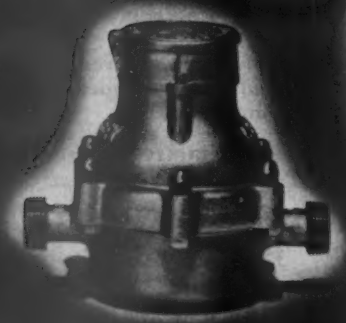

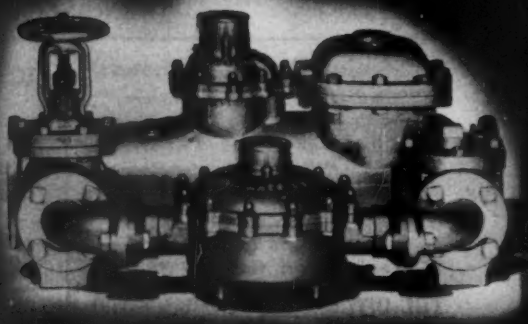

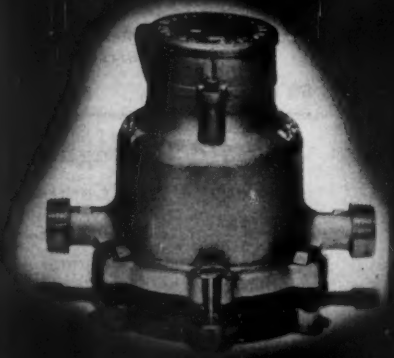

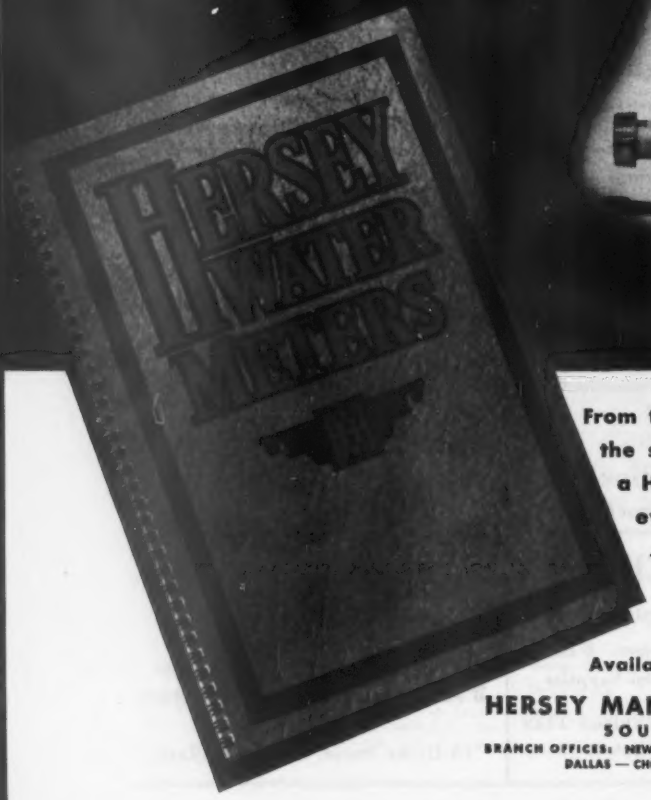

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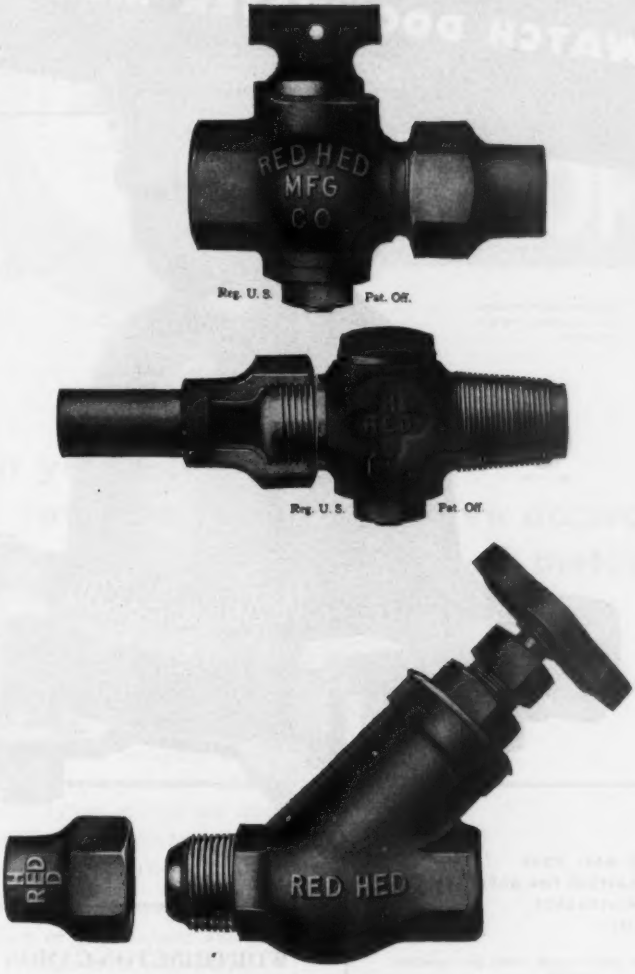

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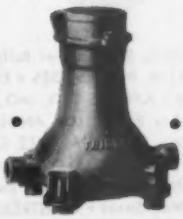

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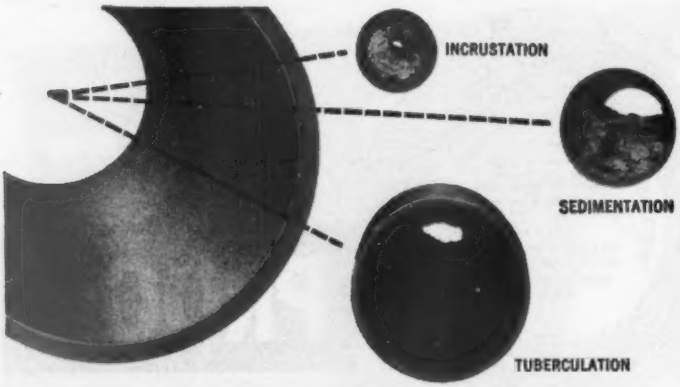

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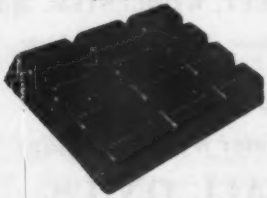

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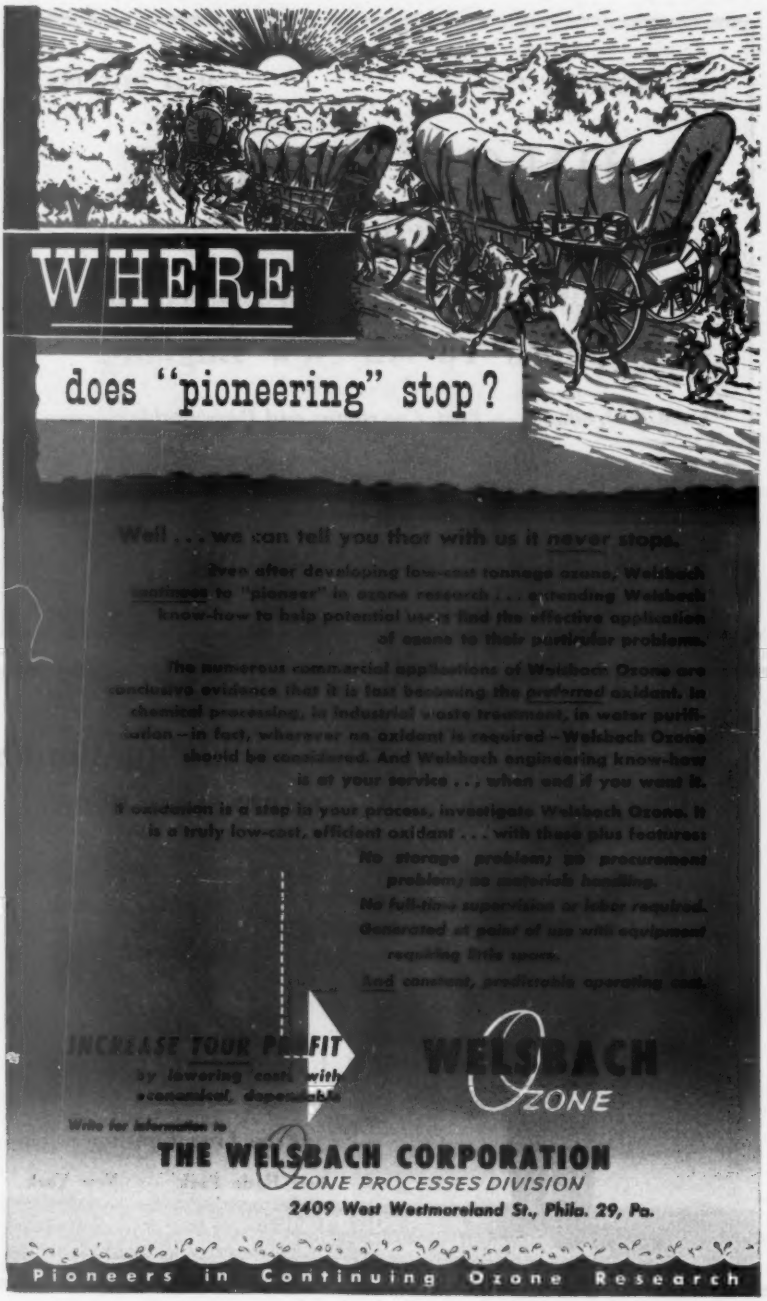
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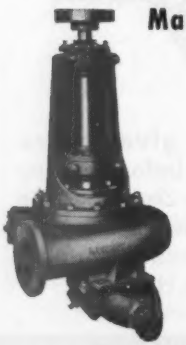

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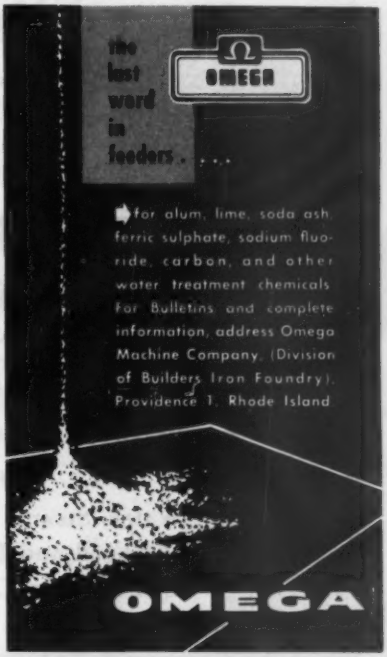
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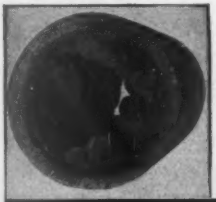

Get Full Service From Old Mains

The most practical way to meet today's overload demand is to clean clogged water mains. FLEXIBLE Underground Pipe Cleaning Co., specializes in such jobs— any size—2" to 72".

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New England Representative

Pipe Founders Sales Corporation

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FOR

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Special Flanged and Bell and Spigot Castings

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Burner, designed by Goss Engineers, burns L-P Gas (commonly known as "Bottled Gas"). Thoroughly tested and proven. Melts approximately 100 lbs. of lead or leadite in 10 minutes. Flame can be adjusted to maintain desired temperature. One cylinder of gas will operate units for many hours.

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Catalog No. 25 FA on Request

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PIPE LINE EQUIPMENT

NEW HYDE PARK **NEW YORK**

1879—ROSS— 1879

AUTOMATIC VALVES

Controls elevation of water in tanks, basins and reservoirs

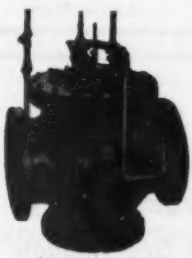
ALTITUDE VALVE

1. Single Acting
2. Double Acting

Maintains desired discharge pressure regardless of change in rate of flow

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

FLOAT VALVE

A self contained unit, with controls three or more automatic

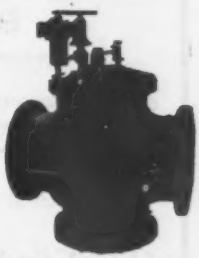
COMBINATION VALVE

Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge

SURGE-RELIEF VALVE

Electric remote control—solenoid or motor can be furnished



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Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

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Radial-Cone Tank
at Cumberland, R. I.

The City of Cumberland, R. I., added this 750,000-gal. Horton Radial-Cone elevated tank in its water distribution system to provide gravity water pressure. The tank is 74-ft. 3-in. in diam., 40-ft. to bottom and has a range in head of 25 ft. We build radial-cone tanks in standard capacities from 500,000 to 3,000,000 gals and ellipsoidal-bottom elevated steel tanks in sizes from 15,000 to 500,000 gals.

We shall be glad to furnish information or quotations on Horton tanks.

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CEMENT LINED SERVICE PIPE:—

Resists Corrosion

Has proven practical for nearly three-quarters of a century

Immediate delivery can be made to waterworks on both wrought iron and steel, black or galvanized.

"SPECIFY EUREKA PIPE"

EUREKA PIPE COMPANY, Inc.

Manufacturers of CENTRIFUGAL CEMENT LINED PIPE and LEAD AND TIN LINED FITTINGS

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FOR SALE:

413′ -4″ (in 18′ lengths) 20″ Bell and Spigot, AWWA class 150, Centrifugally cast, iron pipe new.

Inquire Housing Authority of the City of New London

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Modernization with Rensselaer

The Old Port Washington, Wisconsin, Water plant is now one of the most modern filter plants in the country.

The illustration shows the pump room, entirely equipped with Rensselaer gate and check valves. All gate valves 4 inch and larger in the entire plant are also Rensselaer.

Rensselaer products are well above specifications not only in general characteristics but in the thickness of metal at important points. They are designed with the "know how" which goes back to the early days of water systems, and they are built by technicians many of whom have been with the Company 35 years or more.

You don't have to build a new plant in order to modernize with Rensselaer. Ask our local representative why a replacement of a troublesome check valve will eliminate slam—why Rensselaer tapping sleeves save time, and why Rensselaer hydrants and valves will save maintenance on your service extensions.

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GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES • CHECK VALVES • AIR RELIEF VALVES

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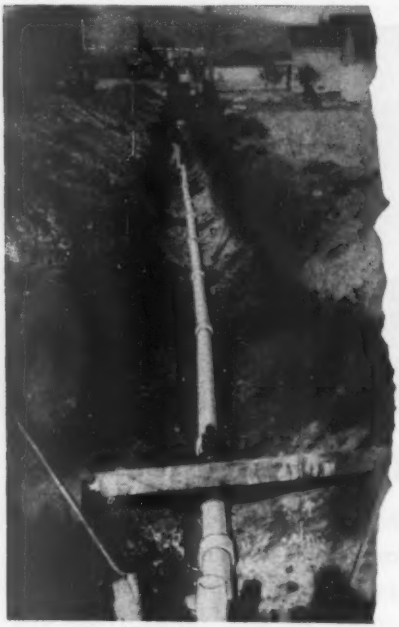

as the trench is dug... "CENTURY" asbestos-cement pipe makes quick work of the main job!

WHEN "Century" Asbestos-Cement Pipe is employed, its installation follows smoothly, economically, and quickly along the trench dug by fast modern machinery . . . as is shown in the picture above.

Put yourself in that trench; "see" how quickly and easily a "Century" water main is installed: it is light in weight, yet because of its inherent strength it needs no coddling. Notice how "Century" Simplex Couplings save hours of trouble as the laying crew keeps up with the trenching machine; curves up to 5° deflection per pipe length are taken easily, special bends are held to a minimum, and flexural strains due to settlement or trench loading are minimized by the flexible couplings.

Now place yourself in the position of an engineer reviewing this job years later. The "Century" Asbestos-Cement Pipe still has the same carrying capacity—because it never tuberculates, rusts or corrodes, its smooth inner surface is permanent. Outwardly it is intact due to its high resistance to the destructive effects of soils. The "Century" Simplex Couplings, though still flexible have become a permanent part of the line. In fact "Century" Asbestos-Cement Pipe actually increases in strength over the years. Therefore if occasion arises it can be re-used at its original classification.

On your next water main specify readily justified "Century" Asbestos-Cement Pipe. Its moderate cost . . . its short, labor-saving installation time . . . and its long, trouble-free, water-carrying life . . . make it the taxpayer's "write-in" favorite!

Write for FREE BOOKLET, "Mains without Maintenance." Gives valuable data, specifications, and reference material for anyone interested in water main pipes.

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K&M best in asbestos

KEASBEY & MATTISON

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to aid peak defense production

Collect and Sell your Iron and Steel Scrap

Mr. Q-Check says *dig* for scrap metal — *search* every nook and corner of your pipe yard—*scrape* the bottom of the barrel! For iron and steel scrap is critically needed to aid peak defense production in steel mills and iron foundries.

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Collect your scrap now. Phone your nearest scrap dealer. He wants what you have *but quick*, and pays good cash prices.

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U.S.
cast iron
PIPE
FOR WATER GAS SEWERAGE AND INDUSTRIAL SERVICE

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Another point, LEADITE saves "interest charges" by speeding up the completion of the water line.

The true value of LEADITE is best indicated by the fact that it has been used on THOUSANDS OF MILES of Water Mains,—all over this Country, as well as in many Overseas Countries.

The Pioneer self-caulking material for c. i. pipe,
Tested and used for over 40 years,
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